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High Voltage Bench PSU

Pulsed Width Modulation Model Train Controller

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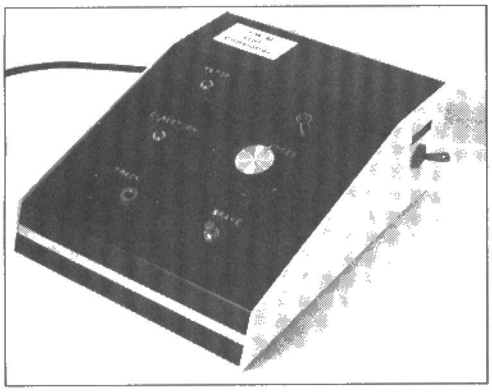

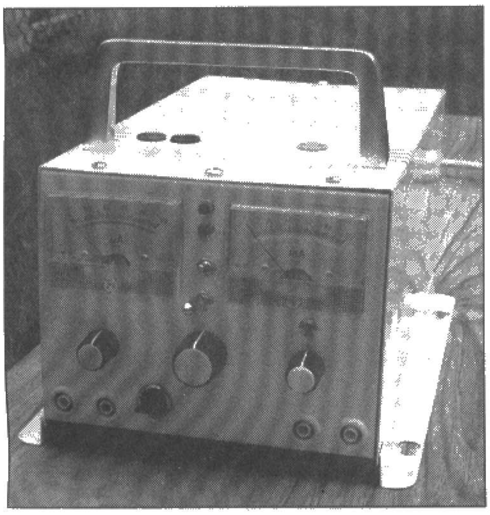

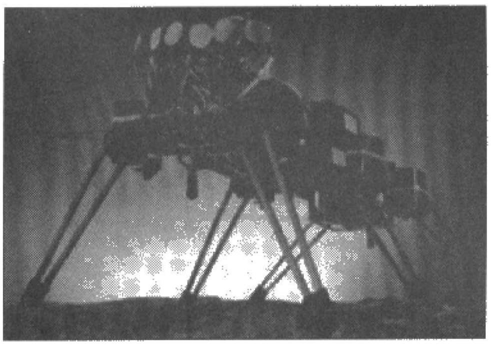

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ETI ELECTRONICS TODAY INTERNATIONAL News...

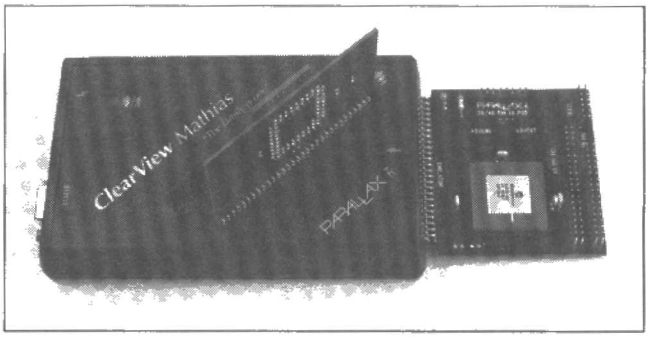
PIC emulators for Windows

Milford Instruments has launched on the market a new series of PIC emulators from Parallax. The Clearview Mathias emulators use modular assemblies to minimise the cost of multi-PIC emulation, and feature full bond-out chips sets to ensure true, PC-independent execution speeds of up to 20 MHz for the 5X series PICs and up to 10 MHz for the 16XX series PICs.

The emulators run under PC Windows 3.1 or Windows '95, and will accept Microchip MPASM, Parallax PASM or code from the Byte Craft C Compiler. Other features include a built-in oscillator giving a choice of 50 operating frequencies, and optional timing and trace modules.

Prices start at £299 for the "Hobbyist" emulator for '5X PICs, £490 for the 16C5X emulator and £550 for an emulator covering the 16C62/63/65/72/73/74 PICs.

For further details contact Milford Instuments, 120 High St., South Milford, Leeds. Tel 01977 683665.
Fax 01977 681465.



National Vintage Communications Fair This Month

The National Vintage Communications Fair, now in its 5th year, is to be held at Hall 3 of London's Wembley Conference Centre on Sunday 1st 1996 from 10.30 to 4pm. Admission is £5, and under-14s are free.

The Fair will be representing: vintage radio and broadcasting; classic audio and hi-fi; early telephones and Post Office equipment; gramophones, phonographs, jukeboxes and recordings; film and television; electrical and mechanical antiques and collectables. Around 300 dealers and collectors from Britain and the Continent will be attending the Fair to sell items relating to early technology and vintage media. Many of the country's leading specialist suppliers, collectors, magazines and clubs will be there to give valuations and advice.

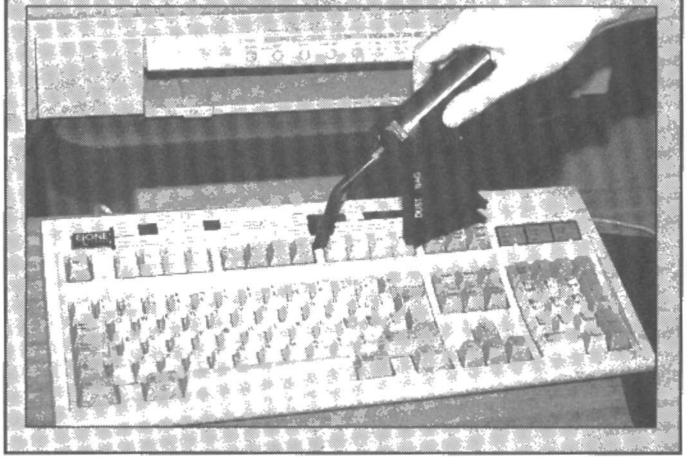
1996 sees a number of anniversaries - the Centenary of Radio, when Marconi arrived in Britian in 1896 to take out the world's first patent for a workable system of wireless communication; the 40th anniversary of BBC television (in 1939 the BBC introduced the world's first high-definition television service from their transmitters in Alexandra Palace in London); the 20th anniversary of The British Vintage Wireless Society in 1976 - and others.

While stocks last, the entry cost of £5 includes a free copy of the NVCF Show Catalogue and Guide.

Further information from NVCF, 2-4 Brook St., Bampton, Devon EX16 9LY. Tel Jonathan Hill on 01398 331532

Mini vacuum cleaner for dark corners

The Jessop Mini Vacuum is one of the kind designed for difficult and fiddly cleaning jobs, featuring a miniature vacuum with an additional blow option plus brush and nozzle attachments to give you access to difficult corners and gaps. The kit includes a dustbag, angled nozzle, and a bottle of cleaning spray, cloth, lint free tissues and cotton buds. The kit is designed for use on electrical equipment such as stereos and computers, as well as telephones and even car interiors. The kit acts to reduce static (and therefore dust) and allows you to clean between switches. And at £9.99, the price seems very good value. Can it remove flying staples from between the keys of a PC? We hope that we won't have another occasion to find out, but it might have saved a certain amount of creative activity with tweezers and glue ... Enquiries to Kathryn Greaves, the Jessop Ground Ltd., tel 0116 232 0033 (Leicester).



Accurate single-channel audio attenuator

A new Overture audio attenuator from National Semiconductor offers the industry's highest level of fidelity for single-channel attenuation with total harmonic distortion (THD) levels of typically 0.001%, and a dynamic range of 110 dB. The device, the LM1971, produces high "pop and click"-free performance from a standard 8-pin, small-outline package. The small space occupied by the device with no loss of performance makes it highly suitable for use in portable communications devices, conference phones, hearing aid devices and other systems where a compact design is essential.

National Semiconductor stresses that traditional single-channel audio attentuation could be achieved only with digitally-controlled potentiometers and resistors designed chiefly for industrial control applications and which did not match the high levels of fidelity of a true audio attenuator. Designed specifically for single-channel audio attenuation, the LM1971 offers a simple and easy-to-design single channel device without the signal degradation associated with pot-and-resistor designs.

In addition to high fidelity and low space requirement, the LM1971 provides a choice of supply voltages from 4.5V to 12V for different applications ranging from low-voltage portable communications devices to digital audio mixers and other professional equipment requiring a highly dynamic range.

In common with an increasing number of devices, the LM1971 is available in standard 8-pin, surface mount and DIP packages. For information about National Semiconductor devices, contact the European Customer Support Centre on tel 00 49 8141 35 1443 fax 00 49 8141 35 1515 (Furstenfeldbruck, Germany). Email europe.support@nsc.com Web site: http://www.national.com

Computer controller dodges round PCs and PLC

Arcom Control Systems has launched a compact computer controller that reconciles industry's need to choose between PLC (programmable logic control) or PC control technology. Based on the powerful new 33 MHz 386EX processor, the module provides the versatility of traditional industrial computer control with the design ease of a PC system, but stripped down and optimised for real-time applications. This delivers high performance without the need to run a heavy duty operating system.

Called Target 386EX, the controller is designed for original equipment manufacturers and builders designing custom control and data acquisition systems.

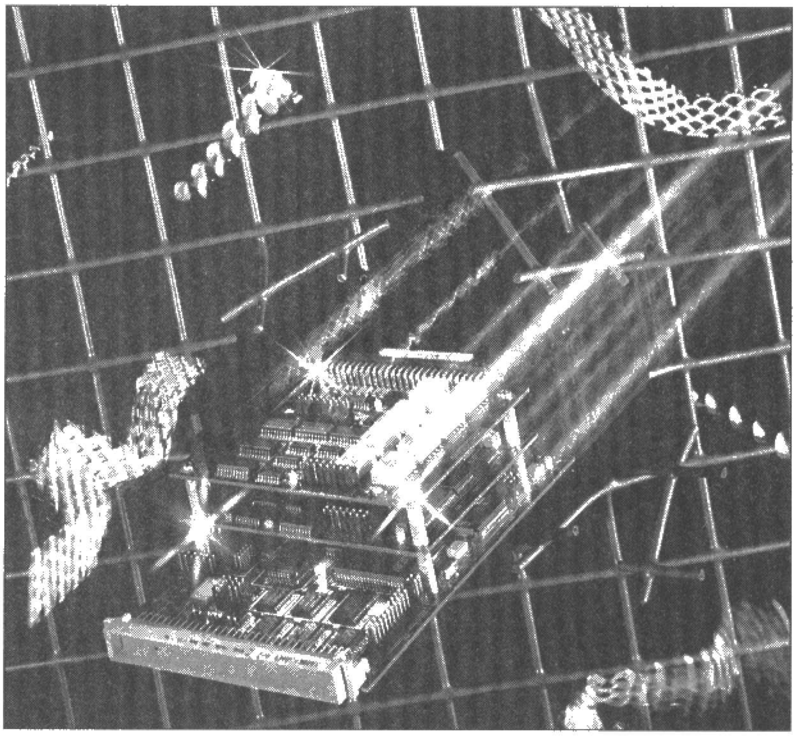
This is one of the areas of commerce and industry that began to migrate from PLCs or custom-designed controllers towards PCs and compatibles from the beginning of the 1990s and are now facing the penalties of larger and more resource-hungry PC systems than existed in the early '90s. Target 386EX resolves this dilemma by providing PC-hosted software development tools and the ability to access PC-type peripherals, but without the necessity of running Windows. This eliminates the need for a massive memory array, hard and floppy disks and additional software royalties, plus the most high-performance CPUs just to run the system - reducing system costs and freeing computing performance for rapid response in real-time situations. Users can configure a small-scale controller with serial and digital I/O for around £380, about one-third of the cost of a system based on an industrial PC chassis.

Two versions of the controller provide on the one hand PC/104 and STEbus extension interfaces for high I/O functionality and real-world interfaces, and on the other hand PC/104 only for simpler system needs such as a single board controller or PC/104 stack.

The system's application development environment is Arcom's SourceView package, available for embedded systems applications over more than five years. The tool runs with industry-standard Windows-hosted compliers such as Borland C, and provides remote source-led debugging for real-time oriented hardware. Arcom also offers an optional multi-tasking kernel with a £24 run-time licence.

Arcom's argument is that the establishment of Windows '95 and Windows NT has undermined the market position of DOS to such an extent that DOS can no longer be regarded as an industry standard upgrade path, and that applications that do not automatically require to run Window-based software should look at other solutions beside PC-based systems.

For further information contact Arcom Control Systems Ltd, Cambridge, tel 01223 411200 fax 01223 410457. Email: sales@arcom.co.uk



The Robobugs of MIT

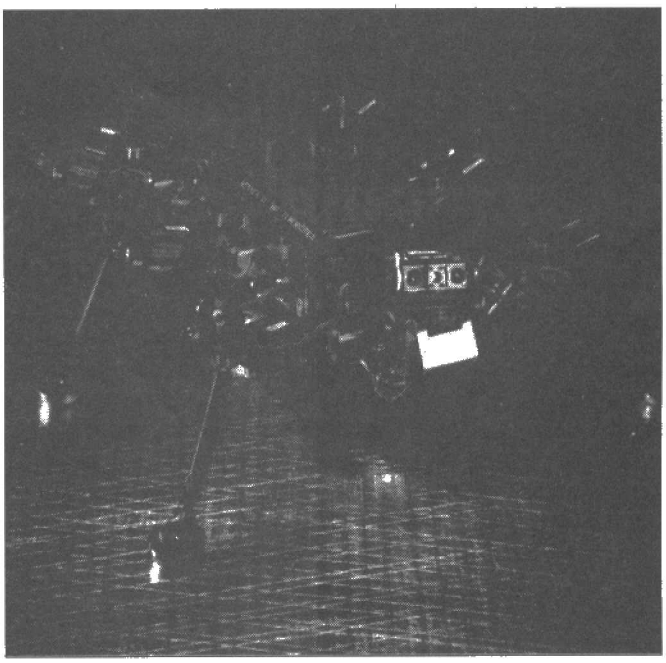
Nick Hamphire takes a look at how colonies of robo-ants and other robotic bugs are crawling out of the insect lab at MIT

Building and designing very small robotic 'insects' may sound a bit pointless - what use could there be for robots weighing a few ounces? But that is what they are doing at the Massachusetts Institute of Technology in the United States. Tiny robots are being used to develop a new approach to intelligent robots.

The traditional approach to designing machines which display some form of intelligent behaviour is an analytical one. The analysis looks at the kind of input the system will receive, and how it will have to respond. The results are used to design the system. But what happens if the system encounters input which was not part of the initial analysis?

The alternative to this 'top down' approach is an evolutionary one, starting with a very simple basic system which gradually grows and develops its own behavioural patterns. This approach - which he calls 'subsumption' is being developed by a team under Professor Rodney Brooks at MIT, and tested with small insect-like autonomous robots or insectoids.

The foot-long robots Ghenghis, Hannibal, and Atilla can walk over rough or sloping terrain and avoid obstacles. These robots show behaviour patterns comparable to insects. Their behaviour was not designed analytically, but emerged gradually.



Legging it ...

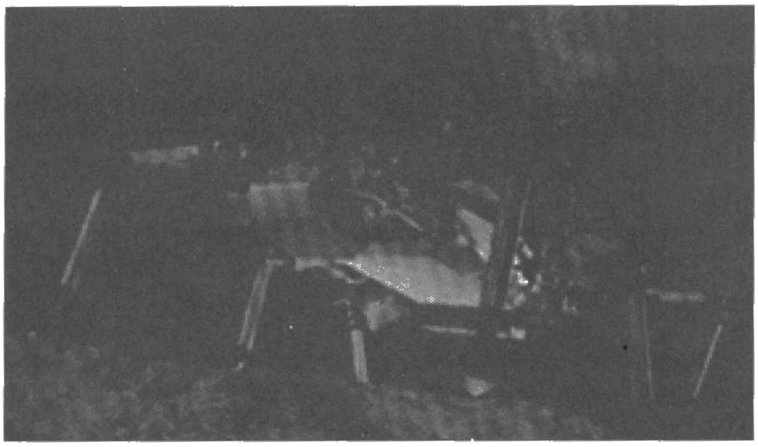
Robot insects are modular, with six identical single legs joined as pairs. Each leg needs two actuators, a Beta Motor to lift and lower it, and an Alpha Motor to move it forward and back.

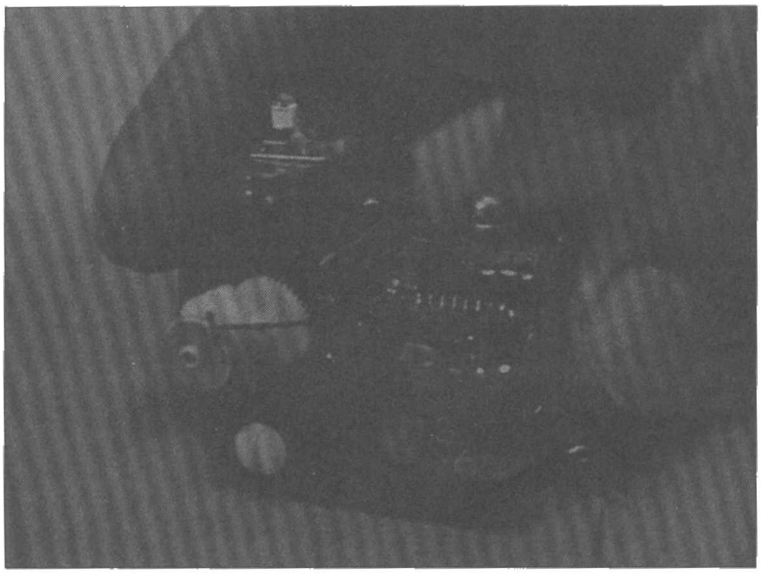
The subsumption philosophy means that each leg has an independent processor that communicates with a higher level processor by transferring a couple of values. Each leg-processor controls its leg-motors in response to commands from the higher processor, and informs the higher processor when the action has been executed. The basic MIT insectoid has one processor for each leg plus one main processor, and two actuators for each leg. Each processor runs software configured as a number of Augmented Finite State Machines (AFSMs) - five for each leg processor, and two for the main processor, making 32 AFSMs in all. The interaction around this network of AFSMs is used to generate simple walking behaviour.

A standard analytic approach to writing control software for robot walking raises difficulties, but with subsumption, much of the complexity can be generated within the system.

The lowest subsumption layer is making the robot stand up. Each leg processor has an AlphaPos AFSM and a BetaPos AFSM to control the actuators. A number sent to one of these causes the related servo motor to turn the leg to the matching *** vertical or lateral position. The supervisor processor is used to transmit to all the AlphaPos and BetaPos AFSMs the right leg position values to get the system - and the robot - to stand up. The legs must be moved first to a zero starting position, and then all together in the right sequence so that the robot stands up in an organised manner, or the robot may fall over ...

The next subsumption layer performs the basic control over walking forward at a set speed, in a straight line, over a level, open floor. With a six legged insectoid robot, when any five legs are touching the ground, the sixth is raised. The legs touching the ground are then swung backwards by a few degrees. The raised leg is then swung forward and placed on the ground. Another leg is raised, and the "grounded" legs swing backwards by a few more degrees, repeating the process.





Control software

The control processor contains the most important elements of the basic walking subsumption layer: the global controller AFSM called Alpha Balance, and a walking sequence master module called Walk. The AFSMs communicate with each other by passing values representing commands or status reports from other AFSMs. The central Alpha Balance AFSM receives continual reports on the position of each leg, and then generates the Alpha actuator swivel commands that move the insectoid. The position of each leg is represented by a positive or negative number, starting with zero when the leg is at 90degrees to the body, with increasing negative values to the rear and increasing positive values to the front. Alpha Balance adds these values together to get an average leg value - a negative sum indicates the average leg pointing backward, and a positive sum forward. When a leg, or legs, swing to the front, a positive value goes back to the Alpha Balance, making the average leg value more positive. Alpha Balance, striving to keep the average leg value around zero, sends a counterbalancing negative value to those legs that are still on the ground. This causes those legs to swivel to the rear, restoring the balance of the system.

The basic insectoid Walk AFSM simply generates the walk sequence, without feedback. Its output is an on/off signal to the network of leg control AFSMs running in the leg processors, and it generally generates a single-sequence pattern at a standard walking speed. However, higher subsumption layers use it to generate different patterns to allow movement at different speeds, walk backwards or turn corners.

So, each leg processor is connected to the main control processor by the command line from the Walk AFSM, and the input and output to the Alpha Balance AFSM. The leg processor also has connections to drive the Alpha and Beta actuators. There will also be limit switches, which prevent the system trying to move past the design limits and perhaps damaging itself, and some form of leg-force or foot-down sensors. To the AlphaPos and BetaPos AFSMs in the standing subsumption level, are added Alpha Advance, Up Leg, and Down Leg. The initiation of leg movement comes via a command line from the Walk AFSM which is connected to the Up Leg AFSM of the leg processor. This starts a sequence of co-ordinated events:

Up Leg sends a negative value to BetaPos, activating the beta actuator and raising the leg. (This counteracts the normal positive value sent by Down Leg which keeps the leg on the ground.) When the leg has risen to the desired level the BetaPos AFSM sends a completed action signal to the Alpha Advance, Up Leg and Down Leg AFSMs. The signal to Alpha Advance generates a positive signal which, sent on to the AlphaPos AFSM, causes the Alpha actuator to swing the leg forward. The signal to Up Leg causes it to cancel the negative value being sent to BetaPos. The signal to Down Leg reactivates the positive signal to BetaPos. As a result, the leg is replaced firmly on the ground in a new position. The catch is that the BetaPos AFSM only raises and lowers the leg to preset positions. On a surface less than completely flat, the leg may "meet the ground" before it is fully lowered, or not at all, which will upset the system and may cause the robot to fall over.

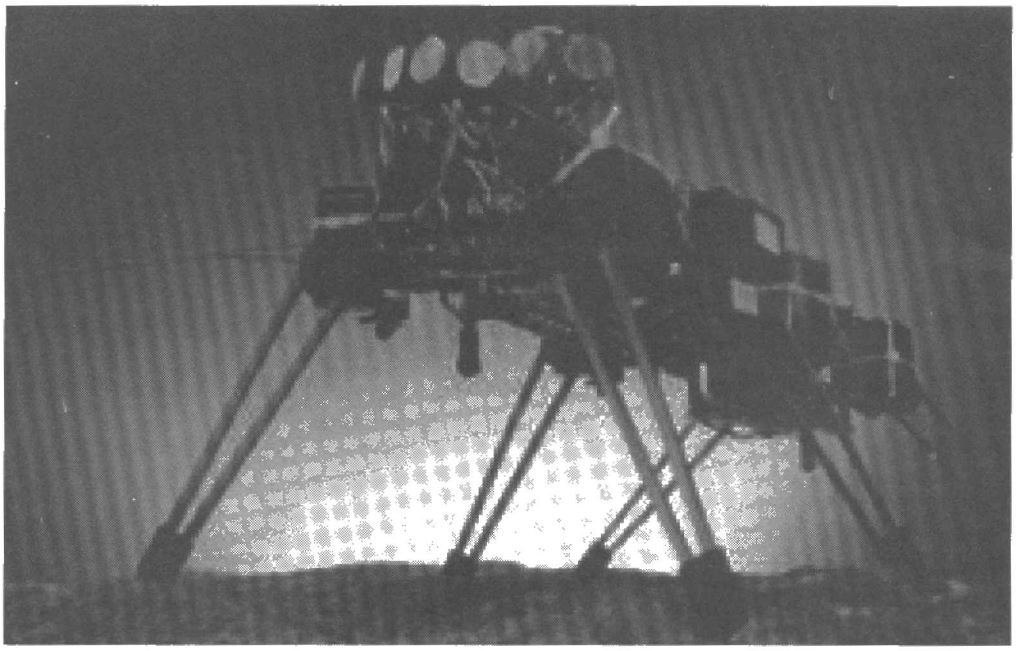
The answer is another level of AFSMs, which receives signals from force sensors on the robot's feet (or by measuring the force applied by the Beta actuator) and tells BetaPos when the leg has actually touched the ground. Further sensors can inform another new AFSM attached to AlphaPos that the forward-swinging leg has hit an obstruction and must be raised higher, or another strategy adopted. Higher levels of subsumption can be added to enable sensors like whiskers or infra-red/ultrasonic range-finders to detect obstacles before a leg makes contact, and allow the system to take evasive action. An interesting alternative (which we talk about below) is to add sensors that can detect something that attracts the insectoid.

Subsumption architecture allow autonomous robots to 'learn' complex behaviour patterns. So far systems have only a few subsumption layers, and there may be a practical limit to the number we can use - but data processing advances every year.

Enter the microbots and robo-ants

Just as the subsumption philosophy allows all the diverse components of a single robot to learn complex behavioural patterns, it can also be used to generate complex behavioural patterns between groups of robots. The biological analogy is with an ant colony, where large numbers of quite simple insects interact to generate the complex behaviour of the colony as a whole.

To test out this idea the MIT, team designed and developed a community of very small robots or micro-robots, some no more than a cubic inch in size, which are known as the Ants. There are two main goals for this project. The first is, as we have already said, to form a structured robotic community from the interactions of many simple individuals, just like an ant colony. The second. is to push the limits of microrobotics by integrating many sensors and actuators into a small package. In order to accomplish these goals, the robots have been equipped with sensors and actuators designed with their natural counterparts in mind. Each robot has 17 sensors, including four light sensors, four IR (infrared) receivers, bump sensors, food sensors, and a tilt sensor. The Ants communicate with each other using two IR emitters, one mounted on the front of the robot and one mounted on the top. Each Ant has an autonomous processor running software based upon the subsumption philosophy. The software on each robot is made up of many little programs, or behaviours. Each behaviour monitors a few of the robot's sensors and outputs a motor command based on those sensor's readings. These commands are then sent to the motors based on a hierarchy; the outputs of more important behaviours override, or subsume, the outputs of less important ones.



The Move to Light program is a very simple example of this approach to programming. This program is made up of only three behaviours, move-forward, move-to-light, and move-from-bumps. Move-forward is always active, it simply makes the robot move forward. Move-to-Light is more important than move-forward. When this behaviour detects light in one the robots light sensors, it heads in that direction, overriding, or subsuming, the output of move-forward. The move-from-bumps behaviour is the most important. It checks the bump sensors and backs the robot away from any obstacles it runs into. When this behaviour is active, it overrides the lower two.

However, when tasks become more complex, one set of behaviours isn't enough to get the job done. In order to make the robots more useful several hierarchies of behaviours are used, with the software switching between them in response to the situation. Each group of behaviours is called a mood.

The evolution of Antware

The Ant robots have been designed specifically to test out the evolution of 'social' behaviour. This once again relies upon the subsumption philosophy and the development of a hierarchy of co-operative behaviour.

At the simplest level there is a 'follow the leader' pattern of behaviour, that can involve anything from two Ants upwards. In this behaviour pattern the first robot transmits the leader signal, and the second one follows, the third one follows the second one, and so on.

The next level of behavioural complexity is clustering. It's very similar to 'follow the leader', but now any robot can head for the leader. Other robots can follow the robot that sees the leader, and still more robots can follow the robot that is following the robot ... and so on for many levels.

After clustering comes a level of behaviour referred to as 'tag' due to its similarity to the children's game. The single "It" robot must seek out and tag - in other words bump into - any of the "Not It" robots. The "It" robot heads for the "Not It" signal that the other robots are transmitting from their IR beacons.

When the "It" robot bumps into anything, it transmits "Tag" from its tag emitter. If the object that was bumped into is a non robotic object such as a wall, the "It" robots does not get a return signal, and continues. If, however, the "It" robot bumped into a "Not It" robot, the "Not It" robot transmits "I got tagged" and then changes its mood from "Not It" to "It". When the former "It" robot receives the "I got Tagged" signal, then it changes it's mood from "It" to "Not It".

The behavioural pattern that involves 'tag' with teams is called 'manhunt'. In this level there are two teams of robots, each trying to tag all the members of the opposing team. When a robot is tagged, it becomes a member of the other team. With this game, different strategies and types of co-operation can be tested against each other.

The next level is the game of 'Capture the Flag'. Two teams of robots are used, as in Manhunt, but the goal is to get the opposing team's flag and bring it to home base. Now the community has to incorporate division of labour, as some robots defend the base while others attack it.

At the manhunt level the MIT researchers have demonstrated simple interaction between groups of Ant robots. However, the ultimate goal is to simulate an ant colony, complete with co-operative foraging, navigation to and from the nest, defence from invading ants, etc.

To enable foraging to take place the Ants are equipped with mandibles that can seize any object encountered on their travels. The robot is fitted with four 'food' sensors which tell the Ant whether the object is food, or not. In the experiments 'food' consists of small balls of crumpled brass foil and the 'food' sensors, two on the mandibles and two on the bump sensors, simply test for electrical conductivity. If it is conductive, then it is food.

When a robot Ant detects the food, it emits an "I found food" IR signal. Any robot within about 12 inches can detect the signal. When a robot receives the "I found food" signal it heads towards the robot with the food, while transmitting "I see an Ant with food". Any robot within range of the second robot receives the "I see an Ant with food" signal, heads towards the second robot, and transmits "I see an Ant that sees an Ant with food". Any robot within range of the third robot receives the "I see an

Ant that sees an Ant with food" signal ...

This behaviour would be useful for efficiently collecting food on foraging trips. Although it is very simple, when combined with other behaviours, and there are many robots interacting with each other, there can be some interesting results.

Conclusion

The interesting thing about the MIT research into insectoids is that they are taking an evolutionary approach to the creation of intelligent robots, an approach which not only deals with single robots but with co-operative societies of robots. Both these areas are extremely important for the future development of robotics, especially robots which are expected to perform tasks in hostile environments without human control or intervention.

If, for example, mankind is to ever explore and colonise Mars then robots will be an essential component of that process. Robots will undoubtedly be used to create the infrastructure that will be essential prior to any long term human habitation. They will have to be very intelligent robots since the considerable delay in radio signals between Earth and Mars would preclude any human assistance. They would also have to be versatile, adaptable, robust, and available in quantity.

The fact that lots of adaptable robots would be used in such an application underlines the importance of developing a complex and rich pattern of behaviour in such a 'robot society'. Having a number of autonomous and otherwise identical robots working together not only allows them to create more complex structures, but also has built in redundancy. The failure of any one robot will not have any significant impact upon the behaviour of the rest - the job will just take a bit longer.

It is interesting to think that robotic insects could be the first colonisers of our solar system, and perhaps even our corner of the universe. Come to think of it, insects were one of the first colonisers of Earth - funny how history repeats itself!

Uses of insectoid robots

The research team at MIT have identified a whole range of potential applications.

Two applications are being examined very seriously thanks to special funding: the design of explosive ordnance disposal robots, and 10-gram micro-rovers for Mars.

The problem of disposing of landmines and anti-personnel mines has attracted a lot of attention recently with world wide calls for their abolition. They are very difficult to detect and remove safely once laid, and are extremely dangerous to civilian populations.

The main focus of MIT's project has been to study how a community of robots can effectively clear an area of unexploded mines and other military ordnance. The team are using micro-robots as a physical simulation of full scale mine gathering mobile robots. They hope that structured behaviour will arise from the local interactions of many simple individuals. For example, if one robot finds a land mine, it can signal its position to others.

The researchers are also looking at the concept of a Mars landing made by a community of micro-rovers weighing no more than about 10gms each. The idea is that a number of very small rovers could spread out and collect data collectively. Each robot has just a few sensors and would be programmed to disperse around the landing area.

The theory is that it might be possible to gather more data using large numbers of micro-rovers than their size would suggest. The concept also allows for greater mission flexibility and reliability. If there are two very interesting rocks in different directions from each other, a single rover would have a difficult time getting to both of them at the same time. Also, if a few of the micro-rovers malfunction, there will be enough left to complete the mission.

This work on ordnance disposal is funded by a grant from the Explosive Ordnance Disposal group of the Navy, and the Mars micro-rovers by NASA JPL.

Technical Specifications of the Ants

Width (excluding whiskers): 1.4 inch
Length (excluding whiskers): 1.4 inch
Height: 1.2 inch
Weight: 1.18 oz

Total battery voltage: 2.4 volts
Battery type: 1.2V Ni-cad cells
Battery life: 20min
Motor stall torque: 0.5 oz/inch
Wheel radius: 0.25inch
Max speed: 0.5 ft/sec
Gear ratio: 59:1

CPU: Motorola M68HC11E9
Clock speed: 2Mhz
Memory: 8k eeprom

4 Infrared receivers; 4 light sensors; 2 bump sensors; 5 food sensors; 1 tilt sensor; 2 mandible position sensors; 1 battery voltage sensor; 1 IR beacon emitter; 1 IR tag emitter; 3 mood LEDs

Future Developments:
Microphones for noise recognition.
A radio link to a stationary computer.
AntCam for simple video processing.

Inside a robo-ant.
The Ants: Hardware

Chassis: The Ants are made using an innovative 3-D print circuit board construction technique. This allows the relatively cheap and easy construction of very small robots. The only drawbacks is that many of the solder joints require accuracy within .005 of an inch.

Treads: The robots method of locomotion is like that of a tank, their treads using a technique called skid steering. The treads are constructed from miniature chain links. If the right and left sides both turn forward, the robot goes forward. If the right side turns forward while the left turns backwards, the robot will rotate clockwise. Different combinations of right and left speeds and directions can be used to get the robots to move in any desired direction

Gearbox: Each robot has three gearboxes, two for the driving motors, and one for the mandibles. The gears come from model aeroplane servos.

Mandibles: Each robot has a pair of mandibles on the front. These work like grippers and allow the Ants to pick up pea-sized objects in their environment. There is a motor in the back that turns a pulley that pulls a string that goes around to the front of the robot that splits into two and pulls each of the jaws in and up. This complex system is used to get the mandibles to perform two actions, grab and then lift, while only using a single motor.

Battery: Ants run off of a single 2.4 volt nickel-cadmium rechargeable battery which allows the robot to run for about 20 minutes.

Battery Voltage Sensor: This sensor give the robots an idea of how "tired" they are. With a full charge, battery voltage is about 2.5 volts. When the voltage drops below 1.5 volts, the robots will cease to operate. They have recharging circuitry built-in so that they can go and recharge themselves automatically.

Microprocessor: The robot's "brain" is an 8-bit MC68HC11E9 microprocessor running at 2Mhz with 8K or EEPROM. A processor approximately equal in power of the first IBM PC. Extensive input/output hardware built right into the chip reducing the need for external components.

Serial Port: Each robot has a little serial port on the side. It can be used for downloading software, or attaching a computer monitoring the status of the robot. There is another serial port on the underside of the robot, made up of a set of conductive pads. This eliminates messing around with small connectors, to program the robot simply put it down on the reprogramming station and hit "enter".

Food Sensors: There are five food sensors, which are actually voltage sensors, two built into the bump sensors, two mounted on the inside surface of both mandible jaws, and one in between the jaws. Two wires that connect the jaw food sensors to the computer. The 'food' is crumpled pieces of brass foil, resting on the conductive surface of the ant farm. The robots are also in contact with this surface, and can measure voltages using it as a ground reference. Anything conductive is shorted to the surface, which is shorted to the robots' ground reference, and will "taste" - just like zero volts. The food objects must be more than just conductive. The robot must be able to get it to touch the middle food sensor before it tries to pick it up - this eliminates big objects that won't fit inside the mandibles. Secondly, the robot has to be able to lift it high enough to break its connection with the ground plane - this eliminates heavy objects. Thirdly, the robot checks that the mandibles are all the way up using the mandible position sensors, to ensure the correct carrying position. Finally, the robot passes a small current from one jaw to the other to make sure there is a good grip on the food. It continues to do this 50 times a second to make sure it still has a good grip on the food.

Bump Sensors: Each robot has two bump sensors. When the robots run in to something solid, the bump sensor wires bend and make contact with a wire loop - a simple microswitch mechanism. The little black balls at the end of the bump sensor wires help to keep the robots from getting tangled up in each other when they are close together.

Tilt Sensor: The small silver object on the top of the robot is a mercury tilt switch. This lets the robot know whether it is on level ground or not. The sensor returns a non-level reading if the robot is tilted at angle of more than about 20 degrees in any direction. When the robots are moving, the mercury shakes around, so the readings are very inaccurate. In order to get good response, the robots need to stop for a second so the mercury inside the sensor can settle down.

Mandible Position Sensors: There are two mandible position sensors, one to let the microprocessor know when the mandibles are open, and one to signal when they are closed. These control the power sent to the mandible motor. A wire at the back of the robot is connected to ground. When the mandibles are closed, this wire shorts with the wire above the mandible gearbox. When the mandibles are open, it shorts out the wire beneath the gearbox.

Mood Lights: There are three LEDs on top of each robot, red, green, and yellow. The software can turn them on and off and flash them at different rates depending on what the robots are doing. They are an essential debugging tool for checking out the software.

IR Beacon Emitter: The robots communicate with each other using infrared signals. Each robot has a beacon emitter, a tag emitter and four receivers. The transmitter on the top is the beacon emitter with a range of about a foot from the robot in all directions. The Ants use this to transmit various things, such as their "mood", what team they are on, where food is, and so on. The signal is transmitted continuously twice a second.

IR Receivers: There is an IR receiver on each side of the robot, which picks up signals from any direction. The operating system monitors these signals, and can track up to sixteen different robots simultaneously.

IR Tag Emitter: The front transmitter is the tag emitter, with a range of about an inch from the front of the robot. The Ants use this to signal when they have bumped into each other.

MAINS-OPERATED LIGHTER SOCKET

***Terry Balbirnie** describes a 12V "car-type" supply that is designed to be used, not in the car, but anywhere there is a mains supply.*

This device will allow a re-chargeable appliance, designed to be plugged into a car cigar lighter socket, to be charged from the mains instead. It will also permit many small pieces of 12V equipment to be powered directly - possible items include razors, torches, camcorders and portable phones. Certain games, small pieces of audio equipment and tools may also be connected. Note that this is a mains project, so attempt it only if you are confident with mains safety.

Be my guest

Since the output is regulated and will never exceed 12.5V, it will be safe to use with all car-type equipment requiring less than 800mA. The author's mobile phone uses about 200mA maximum for battery charging and 400mA while actually in use, so powering this type of equipment is well within the unit's capabilities.

The Mains-Operated Lighter Socket may be carried in the car where it will be ready to operate any of these items while staying with friends, in a hotel or wherever a mains supply is available.

How it works

Referring to the circuit diagram (figure 1), the 240V mains is applied to the primary of transformer, T1. This has twin 15V secondary windings which, in conjunction with diodes D1 and D2, provide a full-wave low-voltage dc output. This is smoothed by capacitor, C1 and applied to the input pin 1 of voltage regulator IC1. On full load, the voltage here will be around 15 to 16V. An accurately controlled 12V supply (within 4%) will then be provided at the output, pin 3. Capacitors C2 and C3 are needed for stable operation of the regulator.

The difference in voltage between unregulated input and regulated output (3 - 4V approximately) appearing between IC1 pins 1 and 3 causes power dissipation. The ic will therefore become warm in operation, so a heat sink is needed. The amount of energy dissipated depends on the current drawn and, at the maximum value of 800mA, will be in the region of 3W. The regulator contains limiting circuitry which prevents internal damage in the event of a short-circuit or overload. Since this limit will be about 2A, greater than the rated output of the transformer, fuse FS1 is included, and will blow at about 1A.

LED1 operates when the low-voltage output is on - this is an LED of a type which does not need an external series resistor. Do not substitute an ordinary LED or it will be destroyed. If you can only get hold of a standard LED, connect a fixed 680-ohm resistor in series with it.

Construction

The component overlay of the single-sided PCB is shown in figure 2. The wiring is simplified by mounting almost everything, including the transformer, on the board. The only items which are mounted off-board are the output socket and LED.

Begin by soldering the transformer in position. Note that

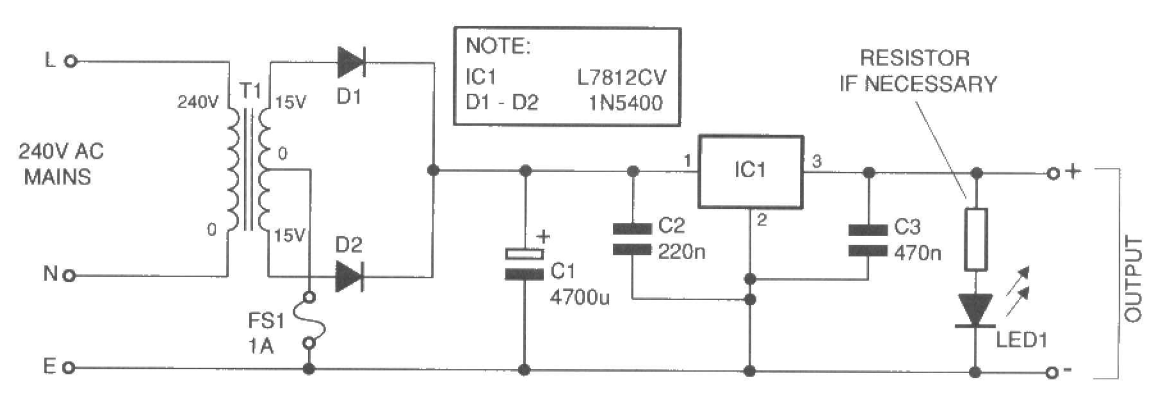


Figure 1: the circuit of the mains-operated lighter socket

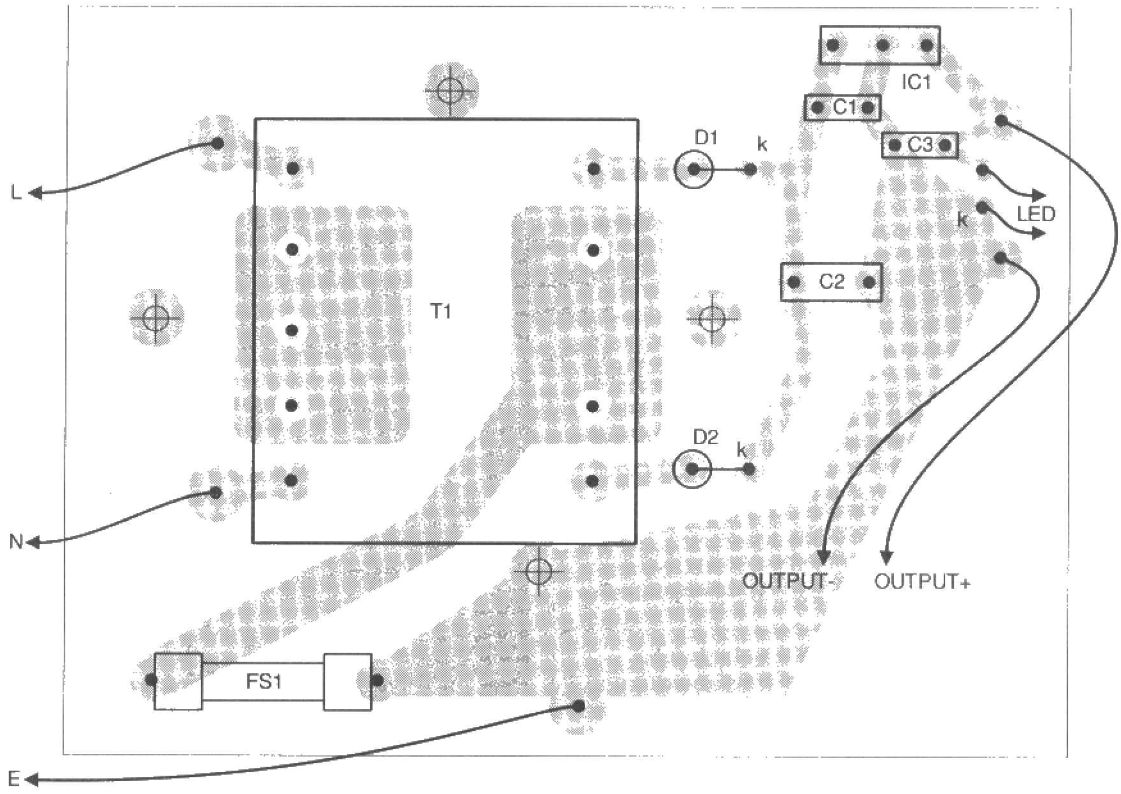


Figure 2: the layout of components on the PCB

some of its pins are not electrically connected, but all are soldered in position to give the comparatively heavy transformer better anchorage to the PCB, as do the large land areas of copper around them.

Next, solder fuse holder FS1 in position. Follow with the diodes - the cathode is the end with the stripe and is labelled "k" on the component overlay. Also note the orientation of C1. Solder two short pieces of insulated connecting wire to the positions marked "LED+" and "LED-". Spread IC1 pins slightly so that they will fit the PCB layout and solder them in position with the metal backing of the device facing outwards from the edge of the board.

Solder 10cm pieces of light-duty stranded connecting wire to the pads labelled "Output+" and "Output-" on the PCB, using red wire for the positive and black for the negative. Solder a 10cm piece of green/yellow mains-type earth wire to the pad marked "E" on the underside of the board.

Get in line

Prepare the box by drilling holes in the base to correspond with those already made in the PCB. Make a small hole for the solder tag, which is used to earth the case and is an essential safety requirement. Drill the hole for the LED indicator, and make the large one for the cigar lighter socket. It seems that chassis-type sockets of this type are not readily available. Only the in-line type is listed by popular suppliers. To mount one of these securely, a vertical type electrolytic capacitor fixing clip of 25mm diameter fitted just behind the mounting hole was used in the prototype. When in position, the body of the socket should lie just behind the hole in its clip.

Drill a hole for the strain relief bush which will be used on the mains input wire. Cut off a piece of 3A flexible mains wire and remove 5cm of the outer insulation. Secure it through the hole with the strain relief bush - essential when attaching mains wiring - around the sheath. Solder the brown and blue wires direct to the "L" and "N" pads respectively on the underside of the PCB. Check carefully that they are secure and cannot detach in service.

Mount the circuit panel on stand-off insulators of sufficient height to make sure that all your soldered ends (including the transformer tags) are well clear of the metal of the case. Since the transformer is a heavy component, the PCB needs adequate support and this is provided by the four fixings adjacent to T1 position. Double check that all soldered connections on the underside have sufficient clearance from the base of the box, and place a sheet of strong cardboard (not the thin 'breakfast cereal packet" type) or tough plastic of a reasonable thickness, or other tough insulating material between these and the bottom of the case - stout enough to prevent any chance of sharp component ends or the primary tags of the transformer poking through and contacting the metal of the case as an additional precaution. Always be careful when handling mains. Double check that there is no possibility of the mains Live and Neutral connections touching the metalwork. Attach the solder tag using the hole drilled previously. Twist together the bare ends of the mains earth wire and the earth wire already soldered to the PCB. Solder these to the solder tag and check that the joint is secure. Wire up the lighter socket noting that the centre connection is the positive one. Attach it in position. Fit the LED indicator and solder the leads from the PCB to its tags, observing the polarity.

Down the sink

The ic needs an adequate heat sink. With some aluminium cases, there will already be metalwork at its position and it may be bolted direct to that. However, if the specified case is used, the sides are part of the lid, not part of the box, so a subsidiary aluminium panel will need to be made - this was 10 cm x 5 cm in the prototype, occupying most of the side area of the box, and it should not be any smaller. It may be secured behind the existing box-end flanges using small countersunk-head self-tapping screws. This will allow the lid section to be fitted correctly. When the ic is attached, check that its pins are not under strain and make any adjustments as necessary. Attach a mains plug to the far end of the input lead and fit a 1A or 2A fuse. Fit the fuse in FS1 fuseholder. Assemble the case checking for trapped wires and short-circuits. Attach self-adhesive plastic feet to the bottom of the case.

Testing is simply a matter of checking for correct operation. It is better not to take the output voltage on trust in case of error, and a voltmeter should be used to confirm this. You will also need a suitable dummy load. A convenient method is to use two car sidelight bulbs of 5W rating, from any motor accessory store. You will also need a cigar lighter type plug. Each bulb requires about 400mA, so the two connected in parallel will draw the maximum permissible current of 800mA from the unit.

Apply the voltmeter probes to the output with no load connected and plug the unit in. There should be a reading of 12V within 4% - that is, up to about 0.5V higher or lower. Apply first one bulb then two, checking the voltage. This will fall slightly with increasing load - by about 0.5V in the prototype. Leave the unit on full load for one hour, checking the temperature of the case at intervals. This will become warm but should not become excessively hot. The voltage at all times should remain above 11V.

PARTS LIST Main Operated Lighter Socket

Parts List for Mains Operated Lighter Socket

Capacitors

C1	4700m 35V radial electrolytic
C2	220n metallised polyester 5mm pin spacing
C3	470n "

Semiconductors

D1, D2	1N5400 50V 3A rectifier diodes
IC1	L7812CV 1A voltage regulator
LED1	Red LED indicator - 12V (NB - type not requiring a series
resistor	- see text).

Miscellaneous

T1	Mains transformer 240V mains primary, twin 0-15V windings
12VA	minimum.
FS1	20mm chassis fuseholder and
1A	fuse to fit.
SK1	Cigar lighter socket - see text.

PCB materials. Insulated spacers for PCB - see

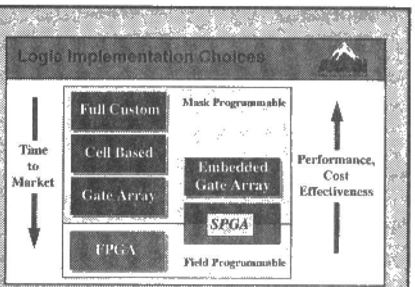
ETI ELECTRONICS TODAY INTERNATIONAL News...

Industrial logic choices combine for the 'best of both worlds'

Two major companies, Actel Corporation and Synopsys Inc, are developing system programmable gate arrays (SPGAs) that will combine the flexibility and ease of application associated with field programmable gate arrays (FPGAs) and the system integration and performance benefits of mask-programmed, application-specific ics (ASICs) in a single chip. By incorporating complex system elements with tradition programmable logic, designers can now implement true programmable "systems on a chip". The areas of application benefiting most from SPGAs with include communications, digital signal processing (DSP), multimedia, embedded systems and computers.

Actel will licence Synopsys' cell-based array (CBA) architecture and the two companies will jointly adapt CBA technology specifically to support SPGAs and develop Synopsis' synthesis technology to support the new devices.

As a new class of device, SPGAs are seen as a good vehicle for combining application-specific blocks with programmable logic for system-level applications on a single chip. Actel are confident that SPGAs represent the first real breakthrough in programmable logic for many years and that designers, who have previously had to choose between time-to-market advantages with FPGAs or efficiency with ASICs, can now have the best of both worlds.



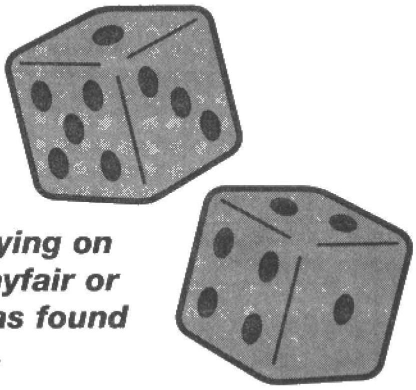
Contact: Actel Information Centre, Direct Mail Systems, 6 Woodbury Lane, Clifton, Bristol BS8 2SD, UK.
Fax 0117 923 9409.

MODSMODSMODSMODSMODS

ETI CAMPLIGHT - OCTOBER 1996

The correct wire for the transformer is 0.20mm insulated copper. D1 can optionally be a BZX79C47 for spike protection. L1as used was Cirkit 34-621-178, L2 was Cirkit 55-50101, but equivalents cn be used.

WINNING DICE



Bart Trepak is fed up relying on Lady Luck to bag him Mayfair or the longest ladder - he has found a wickeder way ...

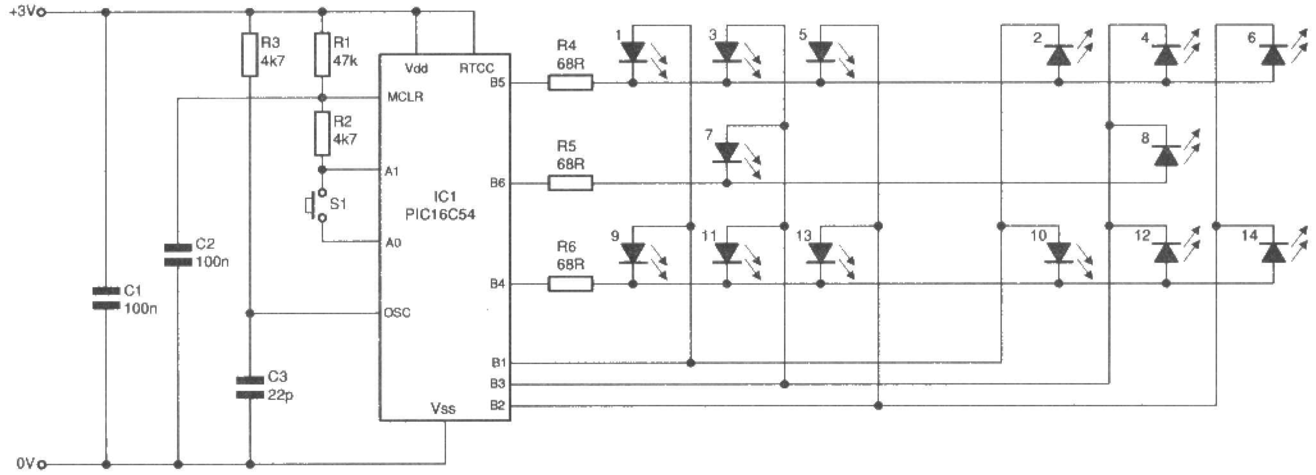


Figure 1: the Winning Dice circuit diagram

At school we were always told that "playing the game" was more important than winning, but once I went out into the big wide world, it soon became apparent that the latter was, to make an understatement, rather important after all. There are not many prizes for coming second or even for being in the winning team, as there is all too often a leader, a captain or a manager to be found to mop up the glory when a team's exertions are crowned with success. Few people know who was the second man to reach the moon or the name of the left back in the team that won the World Cup for England, but everyone remembers the name of the manager. Winning in the game of life is usually a matter of skill and determination (or ruthlessness), but luck also has a large part to play.

With most board games that use dice to control a player's moves, it is almost exclusively luck that determines who will win, although many will no doubt proclaim their special skills when it comes to playing games like Monopoly. Perhaps, like me, you have often watched while competitors raced around the board snapping up all the properties while, by throwing small numbers, you finished up at the end of the queue too late to buy anything but in time to pay rent. Or are you always the last person "home" in Ludo or snakes and ladders? If you sometimes feel that if it were not for bad luck, you would have no luck at all then this is the circuit for you. Successful people often say that they make their own luck, and this circuit enables you to do it in one small area of human endeavour.

Electronic dice have been appearing in the pages of magazines ever since transistors and LEDs appeared on the scene, but not many like this one! To the uninitiated player, there is only one button and pressing it gives a totally random count which is, as with other electronic dice, displayed by LEDs arranged in the familiar dice pattern. It should therefore not be too difficult to convince the other players that this hi-tech solution is much better than throwing conventional dice around which usually end up falling on the floor or knocking pieces over, not to mention the arguments about whether or not if the die had not hit the edge of the board or fallen off the table, a much more advantageous number would have been thrown.

Unlike other dice circuits however, this design has a special ACE (Assisted Count Enhancement) or to use a more politically incorrect term - a CHEAT feature which enables the player "in the know" to consistently throw high scores (double six) or indeed any other number from 2 to 6 as required while other players get a random score depending on their luck.

The circuit

The unit is based on a micro-controller and as such the circuit diagram is unremarkable, except perhaps in the number of

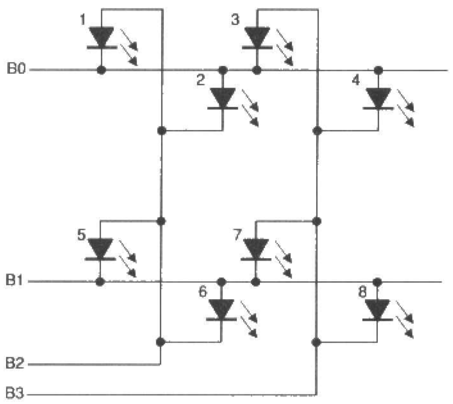


Figure 2: the simplified display circuit

components used - only 21, of which 14 are the LEDs required for the display. The circuit is normally in its "power down" state with all the LEDs off, and therefore consumes virtually no power, so that no on/off switch is required. When the push button is pressed, the processor is reset and a counter is decremented at a fast rate (depending on the on chip oscillator frequency which is around 200kHz with the values of R3 and C3 specified) resulting in a number in the counter which to all intents is random when the button is released. Because the number of different combinations possible with two dice is 36, the count is limited to 36 by loading the counter with this number initially and also each time that the count reaches zero. When the button is released, the count is converted into the required dot pattern, displayed on the LEDs and a software timer started which blanks the display after a few seconds and switches the device off to save battery power.

Resistors R1 and R2 together with capacitor C2 form the reset circuit which wakes up the processor when the switch S1 is pressed by discharging C2 via R2 and port A0 and pulling the MCLR pin low. For this purpose, port A0 is defined as an output and cleared to give a low output before the device is put into the SLEEP mode. Once reset, the capacitor is allowed to recharge via R2 enabling operation to continue because A0 then assumes its high impedance state and is then only switched to output mode for very short periods during operation to sample the switch condition (by reading A1 which is defined as an input) which does not give sufficient time for C2 to discharge via R2 thus holding the MCLR pin high.

LED drivers

The LEDs are driven directly from port B and are connected in a 3x3 "matrix" which is a little unusual but allows up to 18 LEDs to be driven from six lines although here, only 14 LEDs are used. This is possible because the LEDs are, after all, diodes and will light only when a voltage of the correct polarity is applied. The alternative of using one output per LED would require 14 output lines - more than are available on this chip.

The operation is best understood by referring to figure 2, which shows a simplified eight LED circuit arranged as a 2x2 matrix. Suppose the outputs B0-B3 are all low and we want to light LED2. This would be achieved by making B0 positive (logic 1) and leaving B2 negative (logic 0). Unfortunately, LED4 would also be biased on so to prevent this, B3 would also need to be taken positive. This would be fine if only the even LEDs (2,4,6 and 8) were present but in this circuit, LEDs are also connected in inverse parallel and doing this would certainly prevent LED4 from lighting. It would simply light LED7 instead as well as LED2 which is required. Luckily, the outputs of the PIC can also be configured as inputs in which case they present a high impedance and cannot supply enough current to light an LED. The outputs are therefore all programmed as inputs except B0 and B2 which are made outputs and switched to logic 1 and logic 0 respectively. To light LED1 instead, the same lines are programmed as inputs and outputs but this time the logic levels on the two output lines are reversed. In this way, each LED in the matrix can be switched on without affecting any of the others.

This reasoning can easily be extended to larger displays such as the 3x3 matrix used in this circuit. R4, R5 and R6 serve to limit the LED current and since during operation, only one LED is driven at any one time, only three such resistors are required. The display is of course scanned very fast so that the impression of a continuous display is achieved. At the end of the display sequence when the software timer has timed out, the whole of port B is switched to its high impedance state switching all the LEDs off and port A0 is made an output with a logic low level after which the SLEEP instruction is executed causing the micro-controller to switch off and await the next operation of S1.

Note that in this case, a 7x1 matrix could have been used as there are only 14 LEDs to control and this would have saved the above problem with redefining i/o lines each time as well as saving two resistors! The reason for the extravagance in this circuit was that it was developed from an application where over 20 LEDs were required and a 4x3 matrix was used.

Software

To understand how this circuit works, it is necessary to look at the program stored in the on- chip eprom and this is best seen by inspecting the flowchart shown in figure 3. Before this is described, it is perhaps important to realise that every possible number in the dot display can be obtained from four basic dot patterns as shown in figure 4. Thus a display of "1" would be obtained by switching on pattern A while "5" would result from patterns A, B and C being selected. A score of "6" would require patterns B, C and D. The display routines to show these patterns are in fact labelled DISPA, DISPB, DISPC and DISPD and when called energise their respective LEDs in sequence. Calling DISPA will only switch on LED 7 or 8 while calling, say, DISPB would light LED 1 for a short time and then LED 13 or LED 2 and 14. Thus calling the subroutine DISPA followed by subroutine DISPB would result in the appropriate dot pattern for the number 3. Unlike the usual display driving routines encountered in micro-computer programmes however, these routines do not define which particular output lines are to go high and which are to go low but rather their i/o status (ie which are to be outputs and which inputs). Thus, by making B0-B3 low and B4-B7 high before calling these routines, only the 'odd' LEDs (left hand side display in figure 3) will be able to light while loading binary 0000 1111 into port B will enable the 'even' LEDs.

Returning to figure 3, when the switch is closed, the processor is reset and any required registers are initialised. The processor also determines if the reset was due to a power on reset or a wake up from SLEEP condition by reading the appropriate bit (PD) in the STATUS register. If the former, it reads the switch status setting the 'ACE flag as required which will determine if this function is to be enabled or not. The switch is then sampled (A) and as long as it remains closed (ie not released), a counter is decremented. The count continues

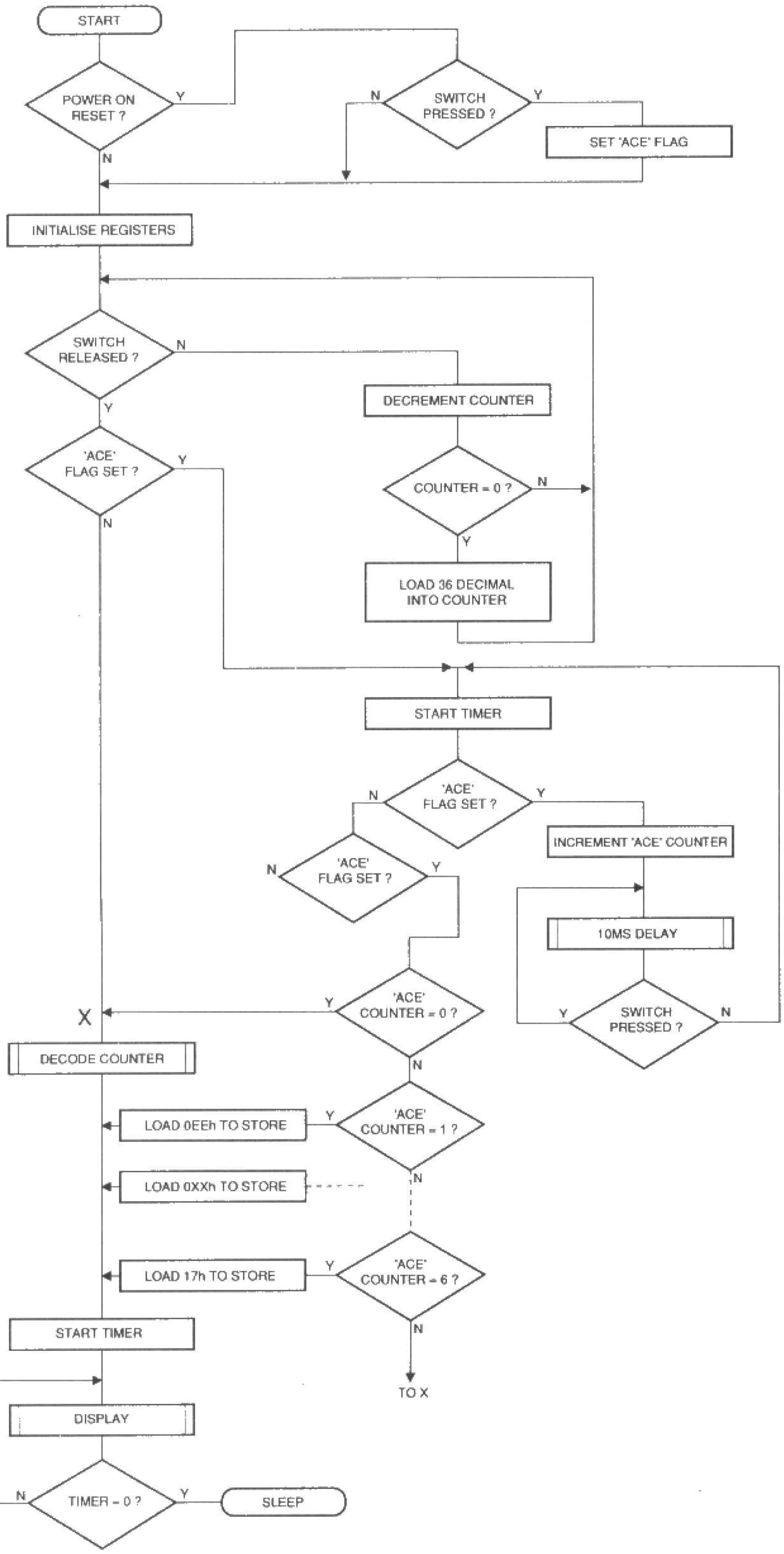


Figure 3: the Winning Dice flowchart

and as mentioned, when zero is reached it is automatically reloaded with 36 (decimal) so that this counter always contains a value between 1 and 36. However, the precise number is unknown because it depends on the initial value and the length of time for which the switch has remained closed. When the switch is released (assuming that the 'ACE feature is disabled), the number in the counter is used to address a look-up table by calling the subroutine called DECODE COUNTER (DECODE in the listing). This returns with an 8-bit number which is stored in a register which, in a flash of creative originality, I called STORE. The lower four bits of this number are used to control one dot display while the upper four control the other. These bits are "tested" in sequence and display DISPA is called up if bit 0 is set, routine DISPB if bit 1 is set and so on. When bits 4,5,6 and 7 are tested, the output drive is reversed so that the LEDs in the second display are energised.

Thus if the counter contained 36 (decimal) at the instant that the switch was released, the decoded number would be 0E7h or 1110 0111 in binary. Since bits 0, 1 and 2 are set and bit 3 is zero, only DISPA, DISPB and DISPC will be called. If 1111 0000 has been loaded into port B, the dot pattern for 5 will be displayed on the 'even' LEDs as LEDs 2 and 12 will fail to light. Port B will then be loaded with 0000 1111 and the four most significant bits in STORE will be tested. Here, bits 5,6 and 7 will be set and bit 4 zero so that only DISPB, DISPC and DISPD will be called. This time only LED7 will fail to light and so a dot pattern for 6 will be displayed. This will be repeated continuously so that although at most only two LEDs are lit at any one time, a display showing 6 5 in the familiar dot pattern will be seen.

A software timer is also started which effectively counts the number of display cycles and after a certain time, the routine is terminated and the device powered down until the switch is again pressed.

Ace up your sleeve

To enable a certain score to be selected, the software is arranged so that the display is not started immediately the switch is released and the observant player will realise that there is a short delay of about half a second between the switch being released and the LEDs lighting. This only serves to enhance the illusion that the display is random but it also has a more sinister purpose if the 'ACE' flag is set. In this case, the program branches at the decision box B in the flowchart and a software timer is started.

If the switch is pressed again before this timer counts out and the display lights, another counter is incremented and the short delay before the display lights is restarted enabling the switch to be pressed again and again if required. If this counter (called the ACE counter), which is reset at the end of each display period, contains a number other than zero, then the STORE register is not loaded with the contents of a location in the look-up table as above, but with a number depending on the number of times the switch has been pressed which will display the required score! Thus, if the switch is pressed and released once following its initial release, the number loaded will be 0EE hex (1110 1110 in binary) which will result in the display routines DISPB, DISPC and DISPD being called for each dot display giving a double six pattern.

During the course of a game, it may also be advantageous to get a smaller score to make it possible to land on a nearby property, or to avoid doing so, when playing Monopoly for example. To make this possible, the software is arranged to count each switch depression and display a score of two for two depressions, three for three depressions and so on up to a maximum of six. Seven depressions will give a random (uncontrolled) display.

Construction

With so few components, it is quite possible to build this unit on strip board although the LED wiring may be found to be a bit tricky. It is therefore recommended that a printed circuit board is used as this will ensure correct wiring and also a neat regular spacing between the LEDs in the display. A suitable layout is shown in figure 5.

None of the components is critical, and any colour LEDs may be used although it is suggested that these are all the same type to ensure a more or less uniform brightness. Note that there are two wire links on the board and these may be made from discarded resistor leads. The micro-controller chip is a CMOS device and should therefore be handled carefully to avoid possible static damage, and the use of a socket for this device is strongly recommended.

While it is obviously possible to mount all the components on the "component" side of the printed circuit board, the prototype was built with the LEDs and switch mounted on the "copper track" side as shown in figure 6. This was done so that the circuit could be mounted in a suitable plastic box by drilling holes at the appropriate places in the front panel and simply pushing the whole assembly into place. Cutting the LED leads flush with the surface of the board on the "component" side will then leave a large area of board free of components which may be used to mount a 2 x AA battery holder to supply the circuit with the required 3 volts. This can be done with a strip of double-sided adhesive tape and result in a neat, self-contained module which can be fitted into any suitable plastic box. Since it is important to get all the LEDs to line up and also standing at the same height from the board, it may be best to solder only one lead on each LED initially and then bend the

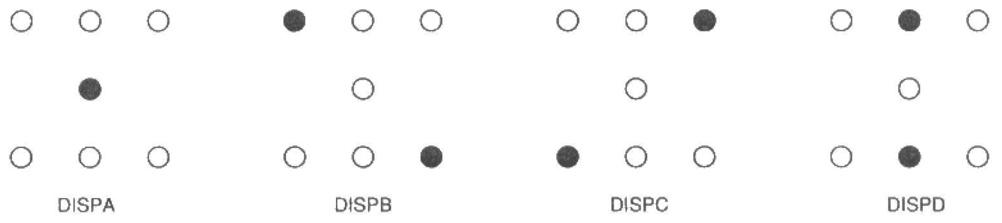


Figure 4: four basic dot patterns

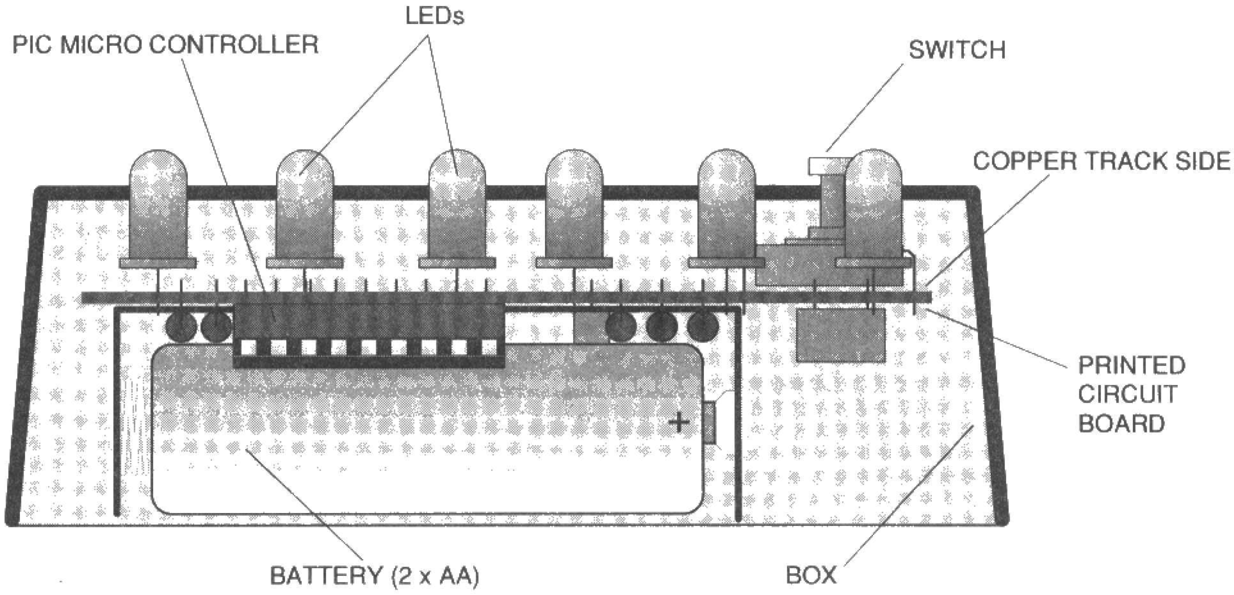


Figure 5: the suggested assembly, showing LEDs and switch mounted on the track side of the PCB

LEDs slightly into line before soldering the other leads. The same height can most easily be achieved by inserting a strip of card cut to the required height between the leads of the LED and pushing the component down as far as it will go before soldering the first lead.

Due to the way the switch will be operated in use, the choice of this component is critical to the success of the project. Although a PCB mounted type was used in the prototype, a panel mounted type may be easier to use and this can be done by simply wiring it to the correct points on the printed circuit board with suitable lengths of wire. It is important that the switch chosen has a "positive feel" (sometimes called tactile feedback) so that the user can easily count the number of times the switch is pressed. For obvious reasons, it must also have a very small "travel" so that only a slight depression is required to operate it, otherwise it will be obvious to other players that the switch is being pressed more than once. For the same reason, it should ideally have no audible "click" as this would be an even greater give-away. This may not be such a problem if the switch is mounted within the box and only the button is external as the click may then be inaudible but in any event, care should be taken when mounting the switch to ensure that the box does not act as a sounding board.

Keep it under your hat ...

Naturally, a powerful game winning device such as this must be used judiciously or other players may begin to smell a rat. Remember the fate of 'poker-faced' playing card sharps in the Old West when their pardners caught them with an ace up their sleeve! If it is said that winning is the most important thing, it is not always said that it is the best way to be popular among the people who you are beating! If, after a long history of losing, you suddenly and consistently begin to 'throw' double-six on every turn and consistently obtain just the right number to enable you to purchase every property you require for your portfolio or fail to land on Mayfair and thereby avoid paying large rents, other players may suspect that your new electronic dice is not as random as it appears ... if someone should notice your finger twitching nervously on the switch before the number you require "miraculously" appears - well, perish the thought. Or you may wish after a while to move your Winning Dice on, like many a successful 'winner' quitting while ahead (or after being caught!) to write a book or concentrate on a showbiz career, to a respectable retirement performing 'magic dice' or 'fortune telling' tricks - to a different audience, of course! Or if pangs of conscience make you decide to "play clean", then a method of switching off the ACE feature will be required.

We can hardly have another switch on the device marked "ACE ON/OFF" without everyone wanting to know what it is for and that might be difficult to explain! Even the operation of an on/off power switch in the middle of a game might be called into question so a more cunning solution has to be found. Using your superior knowledge of electronics, in the event of someone questioning your integrity, you could announce that the double-six may be coming up because the batteries are a bit loose and your finger twitching because of your nervousness at this important point in the game may be causing the battery contact to malfunction. Under this pretext, you can remove the batteries to check/clean the contacts and then replace them, taking care to keep the switch depressed while doing so. This will reset the micro-controller with the ACE function off and then no matter how the switch is operated, the display will be random and unpredictable. Having 'fixed' it, you can then invite your friends to try and score double-six or any other number and indeed even attempt it yourself to show that it must have all been luck thereby preserving your reputation - although you may then go on to lose the game!

Note that the ACE feature can be reinstated by pressing the button seven times following the initial release but this should not be done in the same game or even on subsequent games on the same occasion except in extreme circumstances as the sudden return of your "good luck" may again be questioned. You could of course blame the battery again but this would be likely to elicit calls for a return to the more traditional dice and perhaps more worryingly, call into question not only your integrity but your constructional skills as well! So that it may be better to lose some games gracefully after all. Just like life, really ...

* The PIC micro-controller must be programmed for this application. A programmed device is available from the author together with a suitable pcb mounted switch for £9.50 including UK postage. (overseas orders please add £2).
Send Postal Orders/cheques/overseas Bankers Drafts together with your name and address stating clearly the project you are building (DICE) to: B. Trepack, 20 The Avenue, London W13 8PH.

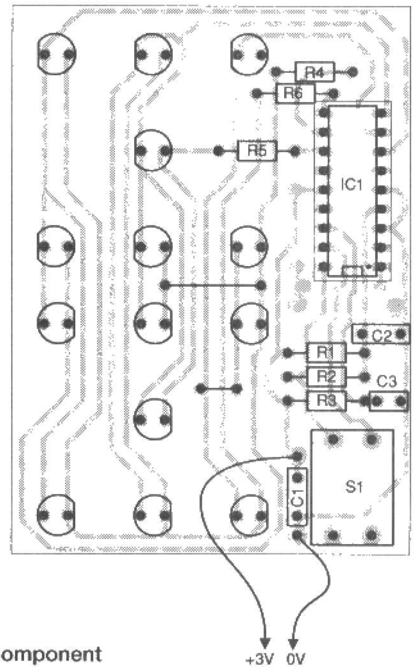


Figure 6: the component layout of the Winning Dice

PARTS LIST

Resistors

R1	47k
R2,R3	4k7
R4,R5,R6	68R

Capacitors

C1,C2	100nF Ceramic
C3	22pF Ceramic

Miscellaneous

IC1	PIC16C54 microcontroller*
S1	Push to make switch*

Printed circuit board, 2x AA battery holder, 18 pin dil socket, box

HIGH VOLTAGE BENCH PSU

by Peter Kenyon

Now that interest in the use of valves has returned to the audio scene, a useful addition to the workshop is a fully regulated power supply with adjustable output voltage and current limit. This is such a power supply, designed specifically with valve equipment in mind.

Specification

The PSU described here is a 40 to 400 volt regulated unit with current limit adjustable between 0mA and l50mA. In addition, there is current sink capability between these limits. Two separate supplies of 6.3 volts ac at 4 amps each are also provided. Front panel meters show voltage and current.

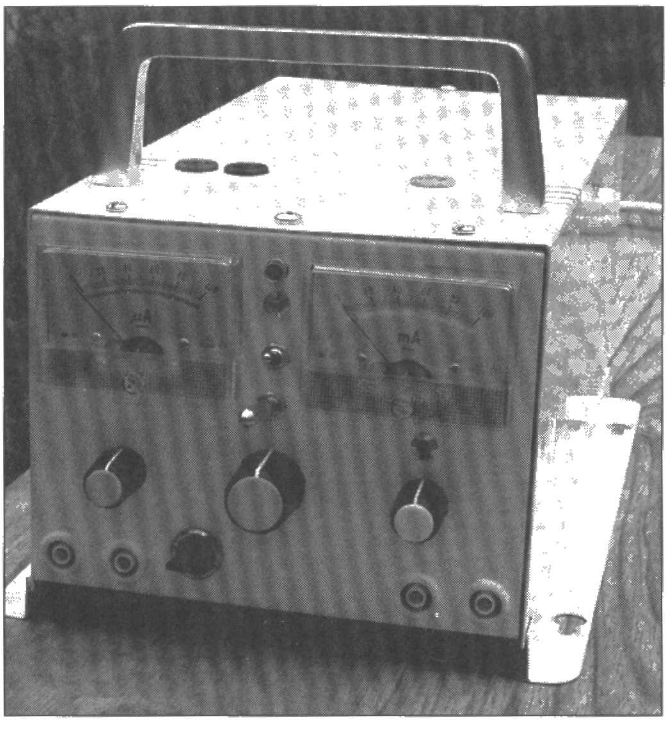
SAFETY WARNING

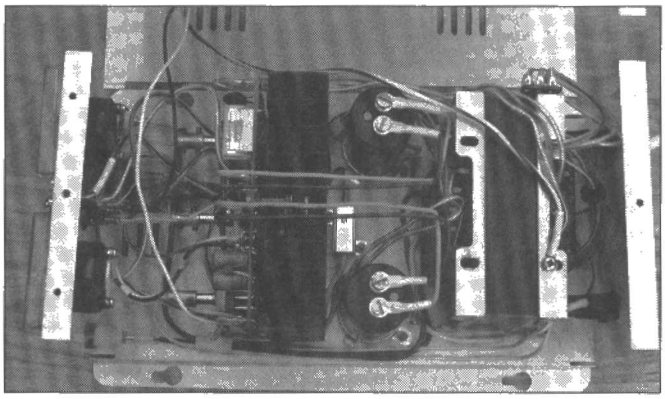
It must be stressed that the voltages involved in this project are potentially lethal. It is recommended that only constructors with experience of high voltages attempt this project.

Design considerations

Only the series pass transistors and main bridge diodes are high voltage semiconductors. An opto-isolator couples the regulating circuit to the series pass transistor.

Automatic switching of the power transformer HT secondary minimises power dissipation in the series pass transistors. A large heat sink is specified for cool running and reliability.





As far as possible, a fail-safe philosophy has been followed in the circuit design. Failure of any of the auxiliary supplies will prevent high voltage from reaching the output terminals. If the series pass transistors fail, however, the full 420 volts on the reservoir capacitor will reach the terminals. This will, of course, be shown on the voltmeter.

In the interests of safety, any modifications to the circuit being powered by this unit must only be carried out after the HT switch and the power switch have been switched off. After a wait of at least 45 seconds, while the reservoir capacitor discharges, power is switched on first (thus warming up the valve heaters), followed by the HT switch.

The power transformer is a custom unit supplied by Sowter Transformers of Ipswich. It combines all five secondary windings in one unit and will make the most economical use of space. Alternative types may be used to provide, for example, a higher output current. In the present design all components are operated well within their limits. Obtaining a higher output current is very simple. A higher output voltage will require more elaborate modifications. Details will be given later for these modifications.

How it works

The rectifier bridge D1-D4 (see figure 1) supplies dc to the reservoir capacitor Cl. TR1a and b are the series-pass transistors, their gates controlled by IC1. BR2, C2, C3 and D9 with D8 supply and stabilise gate bias.

An important rule for op-amps connected as feedback amplifiers is that they will adjust their output to maintain zero volts between the two inputs. The biasing network D14 and D13 hold the negative end of R20 at -6.2 V causing 1mA to flow in R20 (6k2). Kirchoff's law states that current flowing to a point must equal the current flowing from that point. Therefore 1mA must also flow in R5, VRl and VR2 in series. (R11 and R12 across VR2 bring

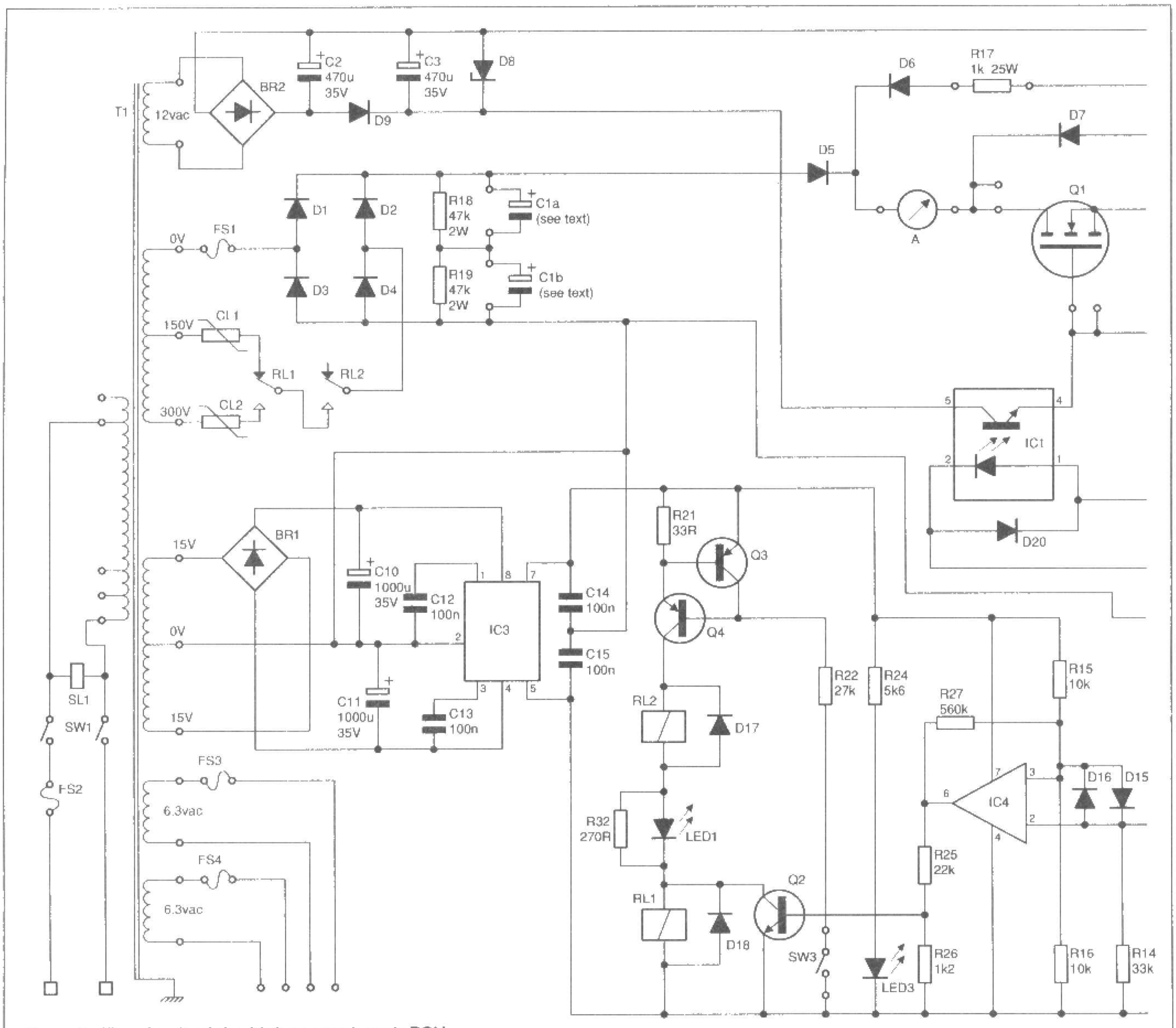


Figure 1: The circuit of the high power bench PSU

their combined value to 313k for the required output voltage range). The output voltage is proportional to (R5+VR1+VR2) in kilohms and is 1 volt per kilohm. (C17, C4, C5, C6 and R4) are necessary for stability. D7 protects TR1. The purpose of D19 will be explained later.

The output of IC2a passes through R3 to the opto-isolator IC1 and into the output of IC2b, the current limiting section. The value of R10 develops 330mV across VR3. Assume, initially, that VR3 is set fully clockwise. So long as the output current causes less than 330mV to be developed across R6 (2R2), then the output of IC2b will be close to the -15V rail. However, if the output current rises above 150mA, then 330mV will be developed across R6 and IC2b output will rise towards the +15V rail, reducing the current through the opto-isolator diode and therefore the output voltage. The output voltage will adjust to that required to maintain 150mA in the load. If VR3 is set to a point where a voltage less than 330mV appears at the non-inverting input of IC2b, then the output current will be limited to a proportionally lower value.

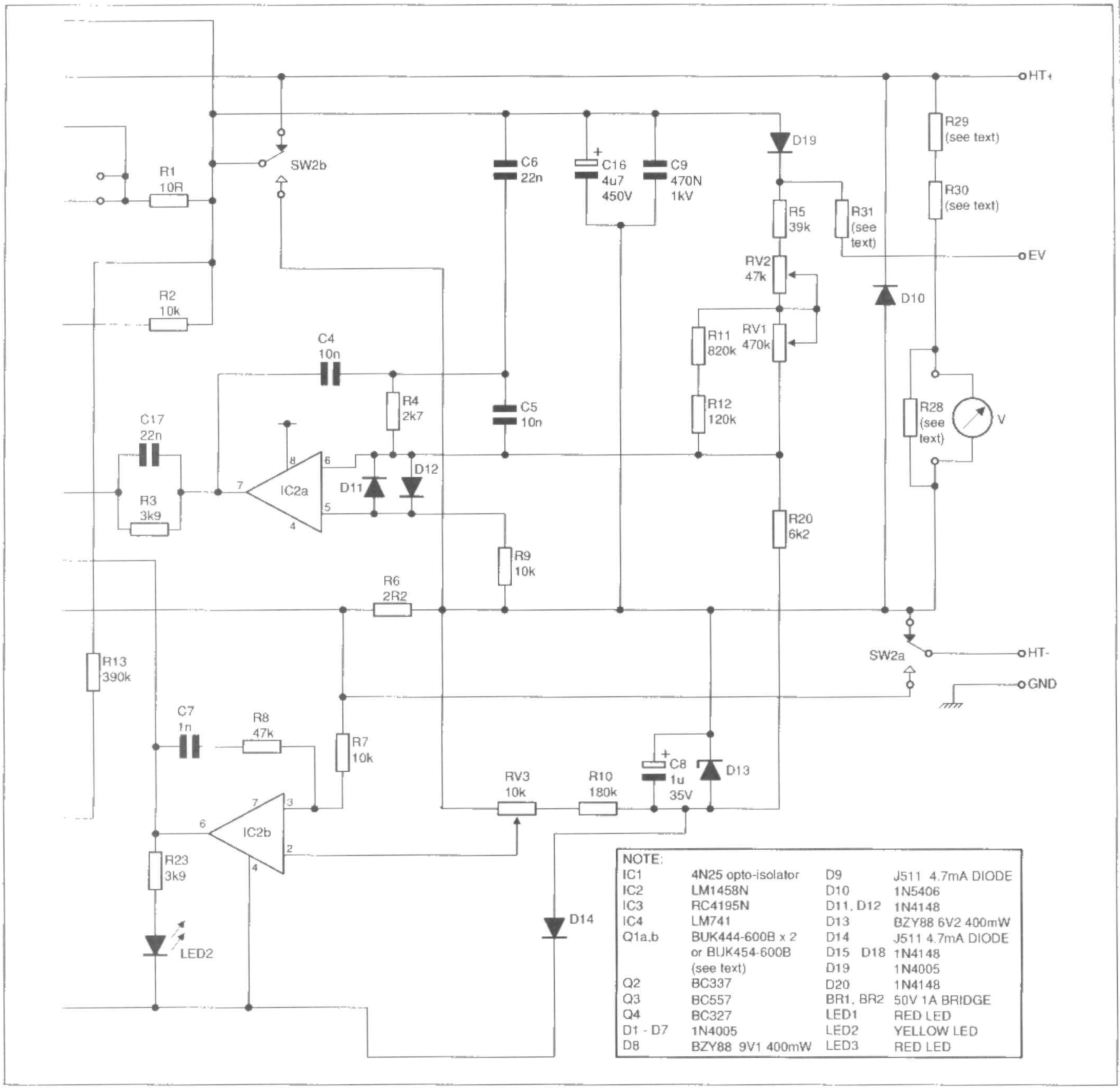
Current sink

To change the function of the unit to a current sink, the locking toggle switch SW2 is moved from "SUPPLY" to "SINK". Current may then be taken from an external power supply for testing purposes up to a maximum 420 volts at 150mA. Higher voltage external units may be connected via an additional series resistor of appropriate value and power rating.

The output terminals then become input terminals of the same polarity. Current flow (conventional rather than electron) is then from the positive terminal through R17, D6 and the meter, through TR1a and b and R1, via SW2b to 0 volts. SW2a ensures that a voltage of the correct polarity is developed across R6, proportional to the current flow, enabling IC2b to control TR1 by the process explained above. In this mode, VR1 and VR2 have no effect, while VR3 controls the current taken in through the input terminals. D10 protects against accidental reversed polarity connection.

IC4 is connected as a simple comparator. When the unit is in the "SUPPLY" mode, the output voltage is compared to the -15 volt rail. If the output is set to more than 180 volts, IC4 output goes low and switches RL1 on via TR2. The 300 volt tap on the power transformer is then selected. R27 provides positive feedback and gives some hysteresis to the circuit to prevent RL1 from chattering.

IC3 is a tracking regulator and provides the stabilised +15 volts and -15 volts rails. SW3 via R22 passes bias current to TR4, which, together with TR3, provides a constant current to relays RL1 and RL2. RL2 is thus controlled directly by SW3 and switches



NOTE:

IC1	4N25 opto-isolator	D9	J511 4.7mA DIODE
IC2	LM1458N	D10	1N5406
IC3	RC4195N	D11, D12	1N4148
IC4	LM741	D13	BZY88 6V2 400mW
Q1a,b	BUK444-600B x 2 or BUK454-600B (see text)	D14	J511 4.7mA DIODE
		D15 D18	1N4148
		D19	1N4005
Q2	BC337	D20	1N4148
Q3	BC557	BR1, BR2	50V 1A BRIDGE
Q4	BC327	LED1	RED LED
D1 - D7	1N4005	LED2	YELLOW LED
D8	BZY88 9V1 400mW	LED3	RED LED

power to the HT bridge while RL1 is controlled by TR2. LED1 indicates that HT is on, LED2 that the regulator has entered the constant current mode and LED3 shows that mains power is being applied to the unit.

Construction

The power unit is constructed on one printed circuit board which is then bolted to the heat sink to form a module. TR1a and TR1b are mounted on the heat sink. This type (BUK444-600B) has an insulated package and, necessarily, a limited power rating compared to the metal package type. This was considered a better choice for the home constructor, since the installation of insulating washers is avoided. However, the constructor may choose to use type BUK454-600B for TR1. This type allows three times the package dissipation and has otherwise identical characteristics.

C1 and R17 are chassis mounted and, since the constructor may make his own choice of metering, only pcb pins are provided on the board.

For safety, the heat sink is installed inside the case. A "transformer" case from Electromail was used for the prototype. This is constructed of mild steel and has generous ventilation slots already cut. Obviously, other cases could be used but, in view of the voltages contained within the unit, safety considerations must prevail when selecting a case.

High tension

All controls are mounted on the front panel along with the 6.3V outputs. The HT terminals, however, are on the lid of the case and are protected by the carry handle. All terminals must be of the fully shrouded type to prevent accidental finger contact.

The low voltage terminals may, in some circuit configurations, be sitting on a large dc potential.

Power switching is carried out via relays. This enables small front panel switches to be used and means fewer high voltage cable runs to the front panel. As previously mentioned, the "Supply/Sink" switch is of the locking toggle type. This will prevent accidental operation, and in any case it should not be operated while power is being drawn from the unit.

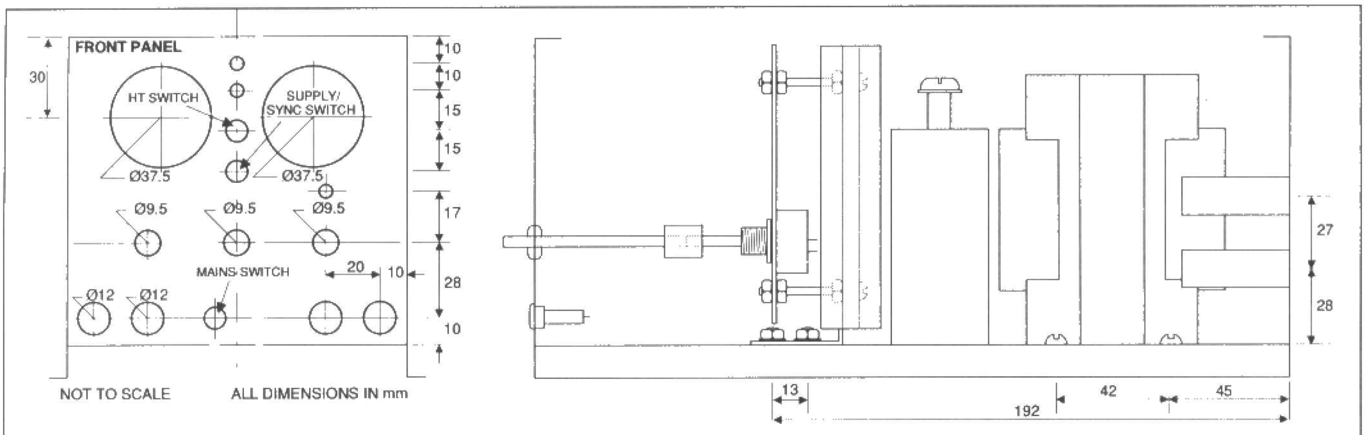


Figure 2: A suggested layout for the case, front elevation and side internal

Cutting the panels

The first part of the construction is to mark out and cut the panels. The dimensions given in figure 2 may be changed, but, if the available pcb is to be used, note should be taken of the position of the control pots. Connections to the pots must be kept short or hum problems will result. In the arrangement I used, the pots are on the board and are operated by the 0.25-inch spindle extensions. The dimensions given take into account the use of the pre-drilled Maplin heatsink (Catalogue ref.JW31J) and which is attached to the chassis with the 'L' bracket (Cat.ref.JP12N).

Marking out the mounting holes for the transformer is best achieved by positioning the transformer inside the chassis and drawing around the holes with a pencil. Bear in mind that the fuseholders protrude into the case by approximately 40mm.

Mark out the holes for the main reservoir capacitor next. In the prototype I used two capacitors in series, each of 500uF at 250 volts working. Since they were in the spares box and previously unused they were pressed into service but the 68uF at 500volts capacitor available from Maplin is equally suitable. The Electromail 35mm clips were used and in marking out the fixing holes, remember to orient the clamp screw for subsequent easy access. NB: The capacitor cans must be isolated from the chassis. If the cans come anywhere near to the metalwork, it would be good to cover them, for instance, with heatshrink sealing or self-amalgamating tape.

Next is the heat sink. It is mounted on the 'L' bracket and an extra hole is drilled on the chassis side of 'L' to keep the heat sink from rotating. M4 screws of 40mm length will be needed to bolt the pcb to the heat sink. Spindle couplers and 0.25-inch nylon rods are used to attach the pots to their respective control knobs. If it is required that the control knobs have a different spacing than is given by the pot positions on the pcb, then 0.25-inch universal couplings can be obtained from most model shops.

The carry handle and HT terminals can be positioned to the constructor's taste on the lid, but it is suggested that the terminals be positioned midway between the front panel and the pcb. This gives the maximum clearance for the connecting cables. The handle can then be positioned 30mm forward from the terminals. It is then easy to insert and withdraw the plugs and the handle gives some physical protection for the plugs. An earth socket is also fitted to the lid, wired to a solder tag held by the handle bolt, with another earth wire taken to the main chassis metalwork.

Wiring

Wiring inside the case can be carried out once the power transformer, fuse and terminals are assembled in the case.

First, identify the transformer wires. If the Sowter unit is being used, the wires are identified as follows:

Approx. resistance 60 ohms:

0V	orange
150V	grey
300V	orange

Approx. resistance 0.1 ohms:

0V	violet
ct	yellow
12.6V	violet

Approx. resistance 42 ohms:

0V	pink
12V	pink

Approx. resistance 28 ohms:

0V	green
ct	white/red
30V	green

The 12.6 volt secondary has been manufactured with the centre tap brought out as two separate enamelled copper conductors inside the same yellow sleeve. These two wires should be separately connected to each of the 6.3V fuseholders on the rear panel. Run a length of 1/1.13mm cable or similar from the other side of the fuseholder to one of the 6.3 volt terminals on the front panel. The other 6.3V secondary is wired similarly, the violet wire being taken directly to the front panel terminal. Sleeves should be added to each of these terminations. Heat-shrink sleeving is ideal. It must be stressed that mechanical security of all interconnections is of great importance.

The mains primary connections to the transformer are as follows:

black	0V
blue	10V
white	210V
red	230V
brown	250V

Approx. resistance (black to brown) is 17.5 ohms. Sowter supply full information with the transformer.

In the prototype the primary connections were all wired to a chocolate block which was then securely fixed to the side of the transformer.

If you will always use the unit on a 240 volt supply, then the blue and brown connections can be permanently connected to the power switch. In this case, the unused wires must be shortened and sleeved. A heavy duty cable gland (Maplin cat. ref. JR76H) takes the mains cable through the rear panel. The brown wire is connected directly to the end tag on the fuse holder. A further length of brown hook-up wire is taken to the power switch from the side tag on the fuseholder.

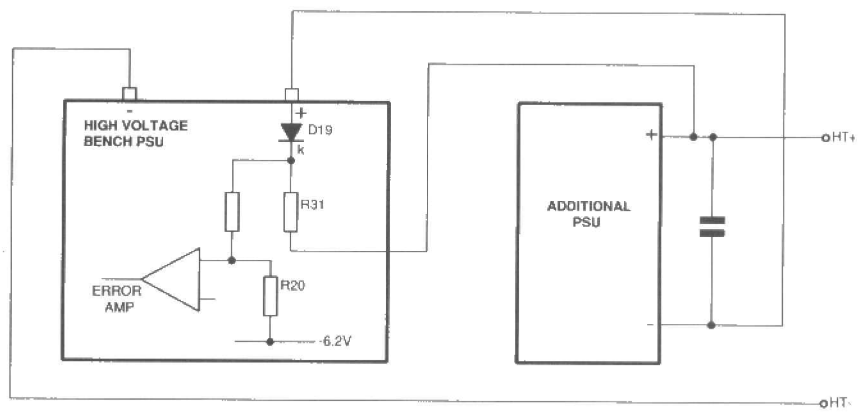
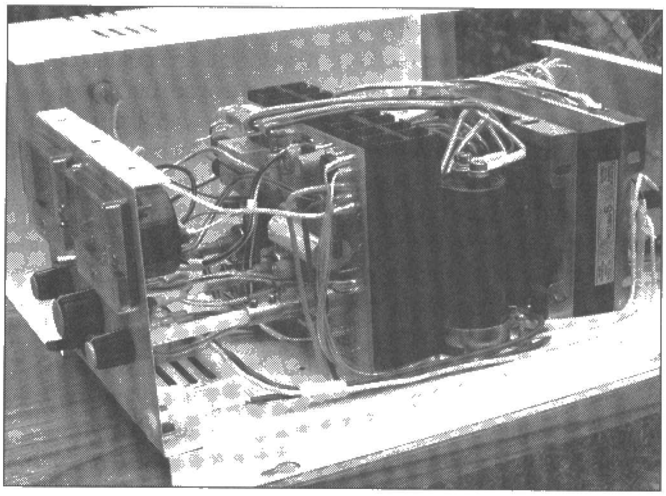


Figure 3: Obtaining higher output voltage



Assembling the pcb

Assembly of the pcb is begun by mounting the low rise components first, including the resistors and diodes, and ending with the high rise component. Most components can be fitted flush to the board, but it should be noted that R18, R19. CL1 and CL2 run hot, and must be fitted 10 or 15mm above the board. Be aware of the orientation of ics, diodes and electrolytic capacitors. I used turned pin IC sockets, but the ics can be soldered direct to the board.

Once pcb assembly is complete, check your work carefully. Mistakes on a board with these voltages can be expensive!

When you are satisfied that all is well, connect leads to TR1 with sleeves, and wire the transistors to the pcb. The pcb, together with TR1, can then be bolted to the heatsink. The transformer secondaries can now be wired to the board pins, again using sleeves for extra mechanical security as well as for insulation.

Cut four single core high current lengths of wire for interconnections between the pcb and Cl. The Maplin capacitor has 5mm screw terminal connections and sleeved solder tags are recommended. If the leads are correctly dressed around the heatsink it will be easy to dismount the pcb/heatsink module when required.

Testing

Once the transformer leads are connected and other wiring is complete, an ohm-meter must be used to check that a high resistance exists between the following points (set VR1 and VR2 fully clockwise):

1) TR1 source to 0V
2) Between drain and source of TR1
3) Across C6 (about 150k)
4) Across C9 (about 1M)
5) Between each 6.3V output and 0V (infinite)
6) Between the HT -ve terminal and chassis (infinite)

Measure the resistance of each transformer winding from their pins on the pcb to double check continuity and correct connection. With no fuse cartridge installed in FS1, some voltage checks with mains power applied can be made. Set VR3 fully clockwise. The output voltage of IC2a should be approximately +14V, IC2b approximately -12.5V and 1C4 output about -13V. The collector of TR2 should be about 0.2V. LED3 should be lit. Turning VR3 to minimum should cause the output of IC2b to change state from -13V to +13V and LED2 should light.

Switch off and isolate the unit from the mains. Install a 250mA fuse in FS1. Re-apply the mains, set SW3 off, VR1 and VR2 to mid-position and switch on. No voltage should appear on the output terminals until SW3 is switched on.

Establish that the output voltage can be adjusted with VR1 and VR2 between 40 and 400 volts. If all is well, a load can be connected. Two 250 volt 25 watt lamps in series will draw about 80mA at 400V.

The function of the current limit control can now be tested. Turn VR3 slowly anti-clockwise. A point will be reached when the output voltage and current will both start to reduce. At the same time LED2 will light, indicating that the unit has entered the constant current mode.

Check that automatic switching of the HT secondary functions correctly. Set VR3 above the current limit point and rotate VRI to vary the output voltage. As the output voltage is swept past the I80 volt point, a click from RL1 will be heard. No other effect should be noticed. The power unit is now ready for use.

Earthing

During use one side of the HT output must be earthed. This will usually be the HT -ve terminal. A third socket is mounted on the lid for this. Sometimes a negative supply is required; for example to provide negative grid bias for output valves. In this case the HT +ve terminal is connected to ground. Note that in some applications it will be appropriate to make the earth connection inside the amplifier being tested to avoid earth loops.

Obtaining higher output current

The power transformer used in the prototype was of I00 VA rating. The HT secondary winding is rated at 150mA. Use of a higher current HT winding is possible provided that consideration is given to heat sinking for TR1. For higher currents, more transistors of the same type

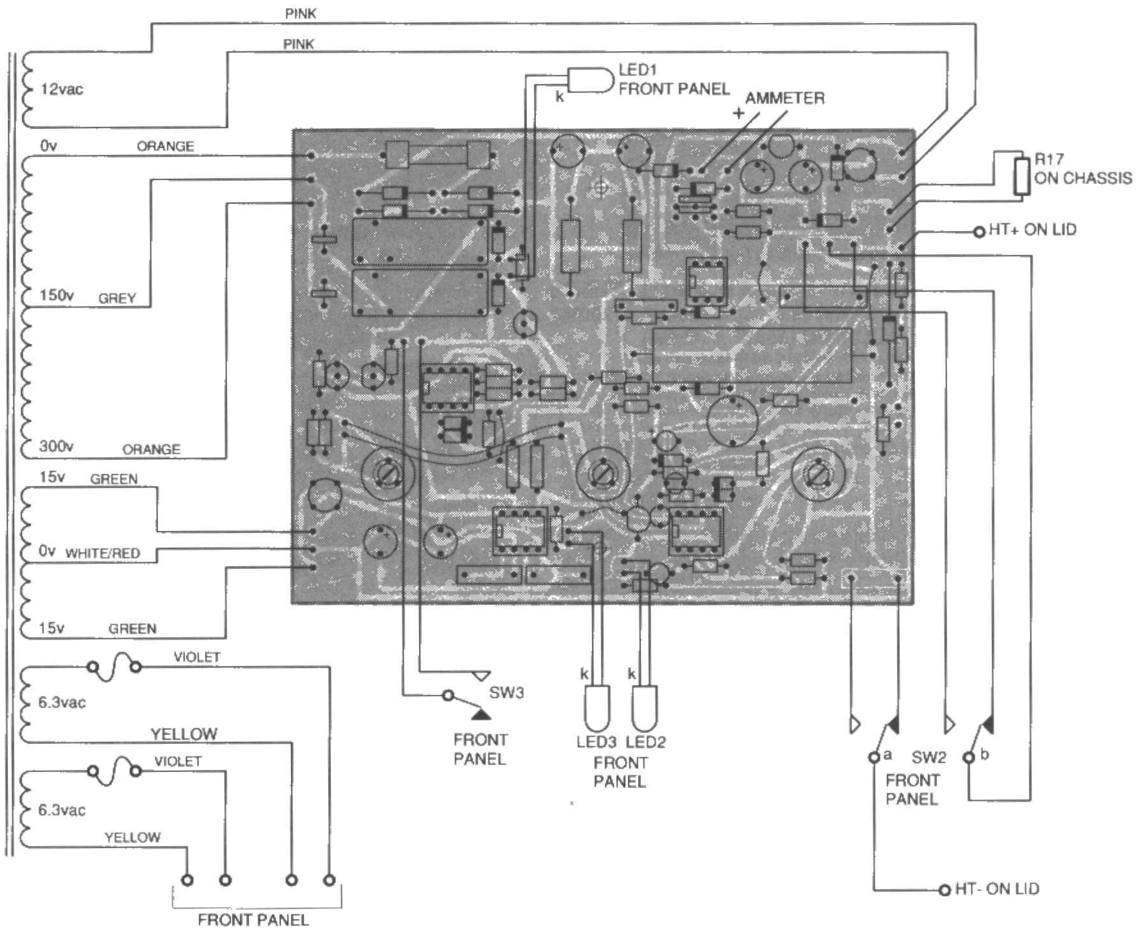
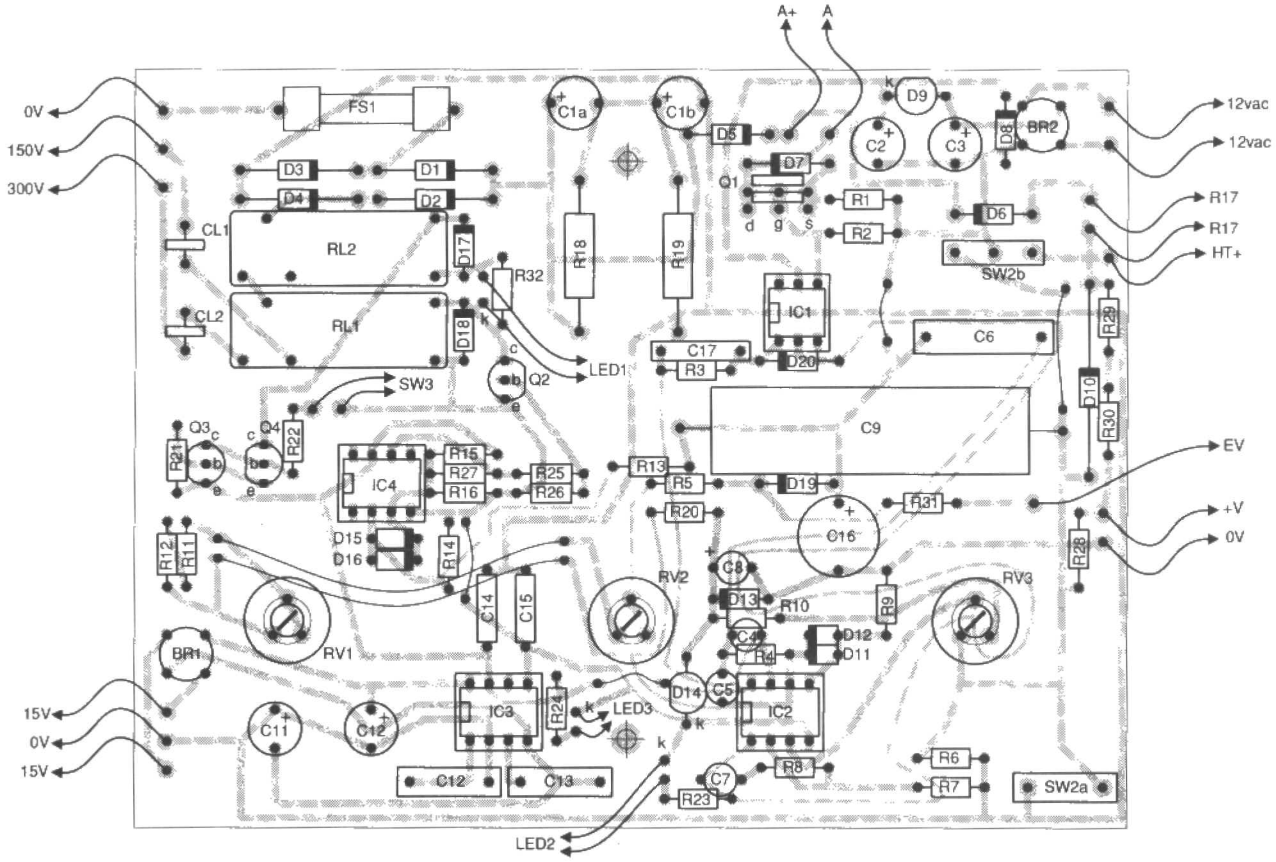


Figure 4: The component layout and the external wiring



can be connected in parallel. Alternatively, use type BUK454-600B with insulating washer. The maximum power dissipation per transistor is then 75 watts. You can use additional heat sinks. Thermal compound between transistor case and heatsink improves heat transfer.

R10 must be changed to enable higher currents to be supplied. If you require 250mA, then the voltage developed across R6 will be, from E=IxR, 250mA x 2R2 0.55volts. This same voltage must also appear across VR3. From I=E/R, I = 0.55/10k = 55uA. Then the voltage across R10 will be 6.2-0.55=5.65V. From R=E/I, R10=5.65/55uA=103k. The nearest preferred value is 100k.

Note that the power dissipation in TR1 is the difference between CI voltage and output voltage multiplied by the output current. For example, if 250 volts is set and 150mA is the current, the power dissipated in TR1 is (420-250) x 0.15 = 25.5 watts.

Obtaining higher output voltage

For greater output voltages up to about 530 volts, an HT winding of 390V rms can be used. This will put up to 552 volts on CI, which must therefore be uprated. TR1 and the diode bridge are rated for 600volts and are within their limits at this voltage. Any increase beyond this will require the uprating of all the 1N4005 diodes and TR1. Heatsinking considerations will also be required.

Alternatively, the arrangement shown in figure 3 can be used. The value of R3 is calculated as before, and is 1 kilohm per volt. Thus an additional PSU with an output of 300volts requires a value of 300k for R3. This combination would give a stabilised output between 340V and 700V. D19 becomes reverse biased in this configuration and the 1mA current flowing to the -6.2V rail flows through R31, R5, VR1 and VR2 to R20.

PARTS LIST

The High Voltage PSU

Resistors

R1	10R
R2,R7,R9,R15,R16	10k
R3,R23	3k9
R4	2k7
R5	39k
R6	2R2
R8	47k
R10	180k
R11	820k
R12	120k
R13	390k
R14	33k
R17	1k 25w
R18,R19	47k 2w
R20	6k2
R21	33R
R22	27k
R26	1k2
R27	560k
R28	see text
R29	see text
R30	see text
R31	see text
R32	270R

Note: R28,R29 & R30 are chosen to suit meter

CL1,CL2	50R current limiter (Electromail 210-673)
SL1	Transient suppressor (Maplin CP76H)
VR1	470k 2W cermet (Electromail 162-883)
VR2	47k 2W cermet (Electromail 162-855)
VR3	10k 2W cermet (Electromail 162-833)

Capacitors

C1a,b	50uF 250V (in series) or 68uF 500v (in parallel)
C2,C3	470uF 35V
C4,C5	10nF polystyrene
C6	22nF 630V polycarbonate
C7	1nF polystyrene
C8	1uF 35V tantalum
C9	470nF 1kv polypropylene
C10,C11	1000uF 35V
C12,C13	I000nF polyester
C14,C15	1000nF polyester
C16	4.7uF 450V
C17	22nF polyester

Semiconductors

IC1	4N25 opto-isolator
IC2	LM1458N
IC3	RC4195N
IC4	LM741
TR1a,b	BUK444-600B x2 or BUK454-600B (see text)
TR2	BC337
TR3	BC557
TR4	BC327
D1 to D7,D19	1N4005
D8	BZY88 9.1V 400mW
D9,D14	J511 4.7mA diode
D10	1N5406
D11,D12,D15,D16 D17,D18,D20	1N4148
D13	BZY88 6.2V 400mW
BR1,BR2,BR3	50V 1.5A bridge
LED1, LED3	red LED (Electromail 585-466)
LED2	yellow LED (Electromail 585-488)

Miscellaneous

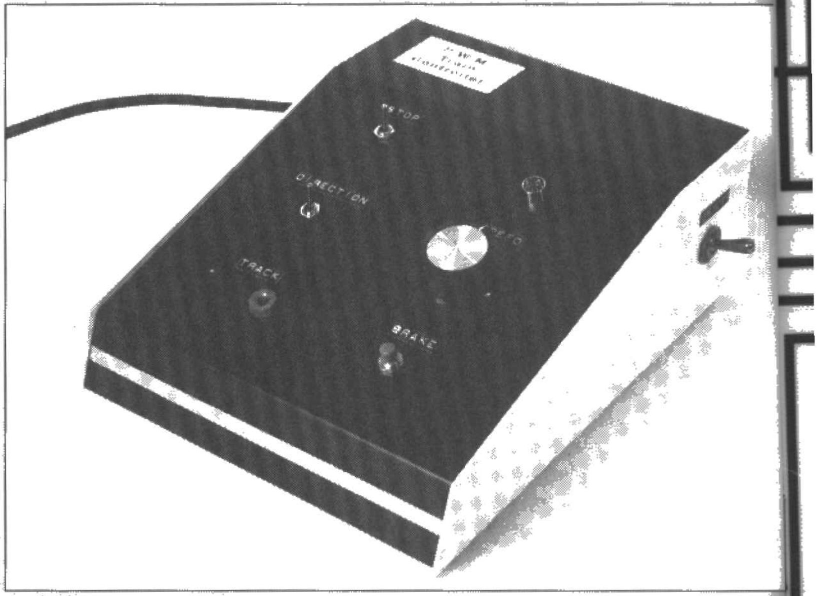
FS1	250mA pcb type (Electromail 419-101)
FS2	IA A/S (Electromail 415-351)
FS3	5A A/S
FS4	5A A/S
T1	Sowter type 8253
RL1, RL2 spco	12V 660 ohms (Electromail 353-203)
SW1 dpst	6A (Electromail 350-232)
SW2 dpdt	locking lever (Electromail 317-588)
SW3 spst	(Electromail 316-973)
Capacitor clip	(Electromail 543-024)
Case	Transformer case (Electromail 220-541)
Heatsink	Maplin JW31J
Sockets	1000V 10A (Electromail Black 404200 Red 40424 Yellow 404266 Green 404222)

Sowter Transformers can be contacted at PO Box 36, Ipswich IP1 2EG. Tel 01473 252794.

PWM TRAIN CONTROLLER

No more jump starts - Robert Penfold's model train controller uses pulse width modulation for a smoother ride.

The model train controllers supplied with many train sets are, to say the least, a bit basic. A simple controller typically consists of a battery pack, a switch, and a few resistors. This gives a couple of speeds in each direction plus an "off" setting. Sometimes variable speed in each direction is provided, but usually via an outsize potentiometer (rheostat) which gives rather poor control.



Jump start

On the face of it, simple methods of speed control are perfectly adequate for this application, but in reality they provide very unrealistic results. The main problem is poor starting performance, with the train tending to jump almost instantly from a stationary position to what is often more than half speed. This is obviously inevitable with a simple controller that only offers something like half and full speed, but it also happens with simple variable speed controllers. The main cause seems to be the starting characteristic of the motor itself which, when under load, seems very reluctant to start. However, the problem is made worse by a simple rheostat speed control.

The motor has a relatively low resistance while the train is stationary. As the speed control is advanced, the current through the motor increases, but the voltage across the motor remains quite low. The speed control therefore has to be well advanced before the voltage and power fed to the motor are high enough to overcome its reluctance to start. Once the motor does start, it sets off at the relatively high speed set on the controller. The resistance of the motor increases once it is turning, giving reduced current flow, but this is to some extent counteracted by an increase in the voltage across the motor.

Speed regulation of a simple controller also tends to be quite poor. Increased loading on the motor produces a reduction in its resistance and a higher current flow, but there is also a reduction in the voltage fed to the motor. Reduced loading gives higher resistance through the motor and a lower current flow, but the voltage fed to the motor is increased. In either case the power fed to the motor changes very little, and speed regulation is not very good. The problem is worst at low speeds where the train will stall at the slightest excuse.

Pulsed control

Improved results are produced using a so-called constant voltage controller, which is basically just a variable voltage stabilised supply. The output voltage is constant in the sense that for a given speed setting it does not change, despite any variations in loading. This method of control provides better speed regulation, because any variation in loading gives a corresponding change in current flow, but without any change in the drive voltage. The motor can therefore draw more or less power, as required.

Although the constant voltage approach gives improved performance, it does not give the ultimate in performance. Speed regulation is quite good, but in order to give really good results it is necessary to use what is effectively an overcompensated voltage regulator. In other words, when the motor draws more current, the voltage fed to it actually rises slightly. Similarly, when the motor draws less current, the output voltage of the controller falls slightly.

This still leaves the problem of poor starting performance. Probably the best way of handling this is to use pulsed control. Rather than feeding the motor with a simple dc voltage, it is fed with a pulse signal. The waveforms of figure 1 helps to explain the way in which this method of control operates. In each case the signal has maximum and minimum potentials of 0 volts and 12 volts.

In the top waveform the signal has a mark-space ratio of 1:1. With the signal at 12 volts for 50 percent of the time, the average output voltage is six volts. In the middle waveform the mark-space ratio is 3:1, which means that the output is at 12 volts for 75 percent of the time. This clearly gives an average output potential of nine volts. In the bottom waveform the mark-space ratio is 1:3, giving an output signal that is at 12 volts for just 25 percent of the time. The average output potential of this signal is just three volts.

fBy varying the mark-space ratio of the signal it is possible to obtained any desired average output voltage from 0 to 12 volts. The dc electric motor in the train will work perfectly well from a pulsed signal provided it is at a suitable frequency. Setting the frequency too low gives jerky operation, with the train responding to individual pulses. With a frequency of about 25Hz or more the train will move along reasonably smoothly, responding to the average output potential. High frequencies are not suitable as the motor might offer a high impedance at these frequencies, giving too little current flow. Also, the tracks would almost certainly radiate illegal radio frequency interference (rfi).

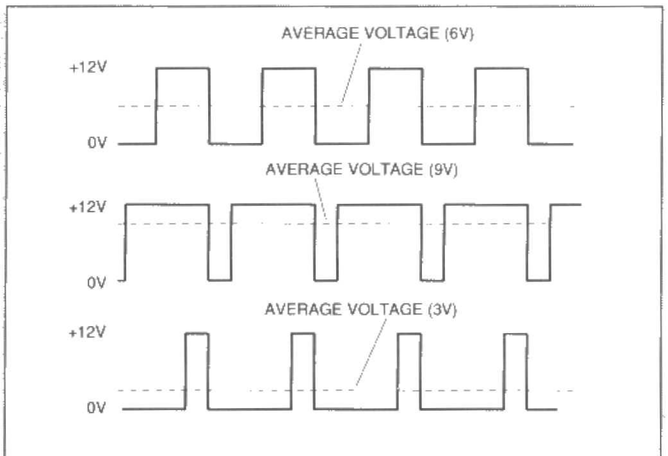


Figure 1: Example waveforms for a pulsed train controller

Although there may be no obvious advantage in pulsed control, it does actually give much improved starting and low speed performance. The crucial factor here is that the motor is switched on at full power during each pulse. This tends to nudge an otherwise reluctant train into action, giving much better starting performance. It also makes the train less prone to stalling at slow speeds.

The improvement in performance compared to a constant voltage controller is quite marked. Making the train slowly and realistically pull away from a station is perfectly straightforward. Trains can be made to loop the track at very slow speeds, and stalling normally occurs only if the motor loses electrical contact with the controller. Provided the tracks and pickup wheels are kept reasonably clean, this should not occur.

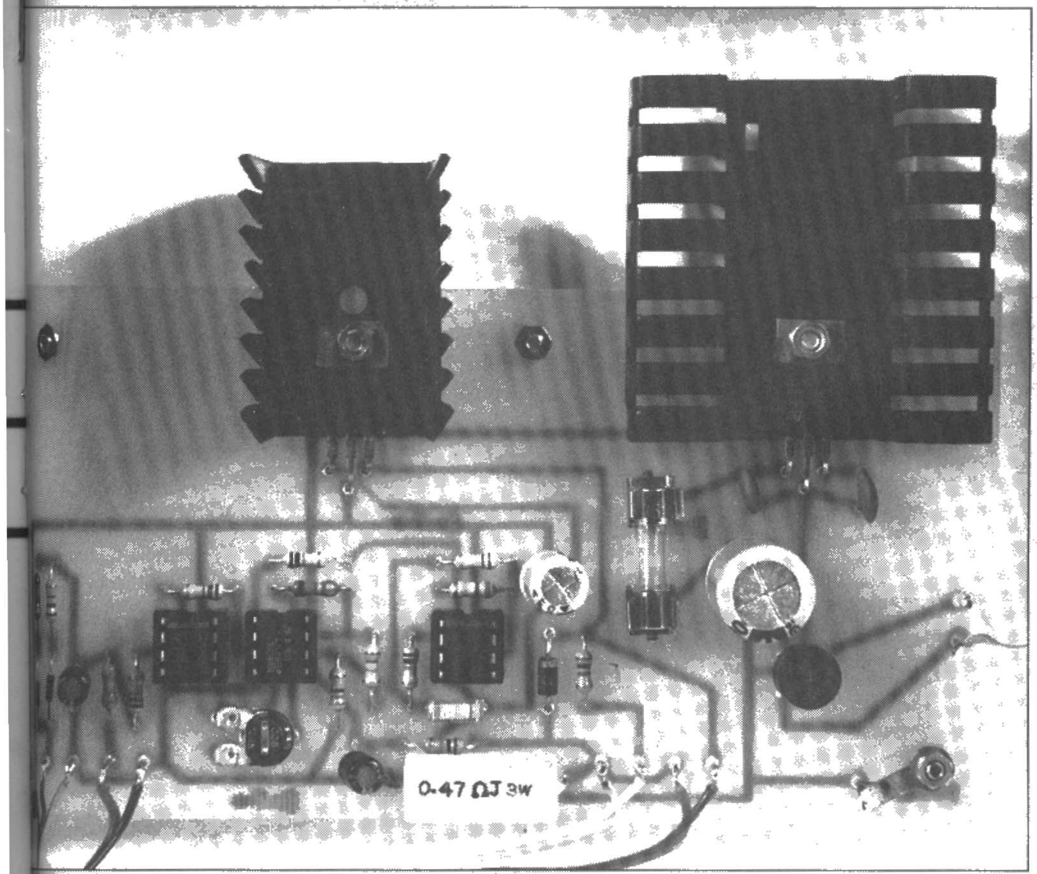
Best of both worlds

The model train controller featured here is reasonably simple, but it incorporates both pulsed control and overcompensation. This gives the ultimate in starting and slow speed performance. The unit has a built-in mains power supply which incorporates foldback current limiting to protect the model train and the controller itself if an overload should occur. The circuit also incorporates simulated inertia, momentum, and braking.

In other words, there is a delay between the speed control being advanced and the train accelerating to the set speed. This simulates the inertia of a real train. With the speed control backed off, the train coasts for a considerable period before coming to a halt. This simulates the momentum of the "real thing". The train can be decelerated more rapidly by pressing the "brake" button. This method of control makes driving the model train more challenging and more fun, but circuit is easily modified to operate with a straightforward speed control if preferred.

Figure 2 shows the block diagram for the pulsed train controller. Conventionally, the pulse signal would be generated by a pulse width modulator consisting of a clock oscillator and a comparator. This circuit would produce a pulsed signal having an average output potential equal to the dc input voltage. This design utilises a slightly simplified arrangement that effectively integrates the comparator with the oscillator stage. The oscillator drives the electric motor via a buffer stage which enables output currents of up to an amp or so to be provided.

The speed control potentiometer feeds into a C-R timing circuit which supplies attack and decay times that give the simulated inertia and momentum. The brake control is included in this part of the circuit. A buffer amplifier ensures that the attack and decay times of this circuit are not significantly affected by loading of the subsequent stage. The control voltage is fed to the input of the pwm oscillator via



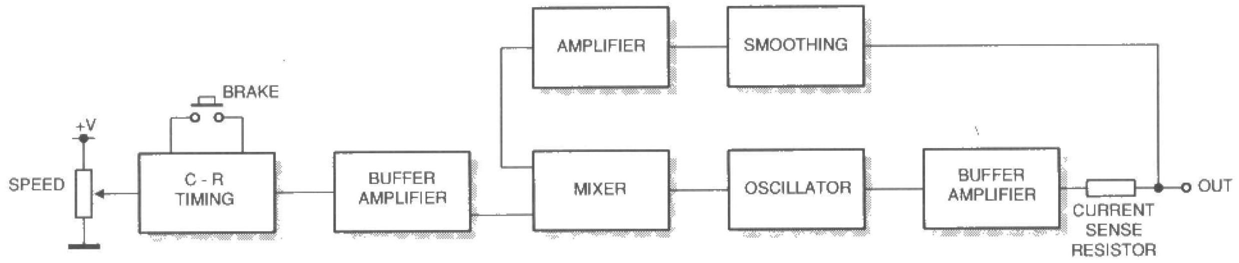


Figure 2: The pulsed train controller block diagram

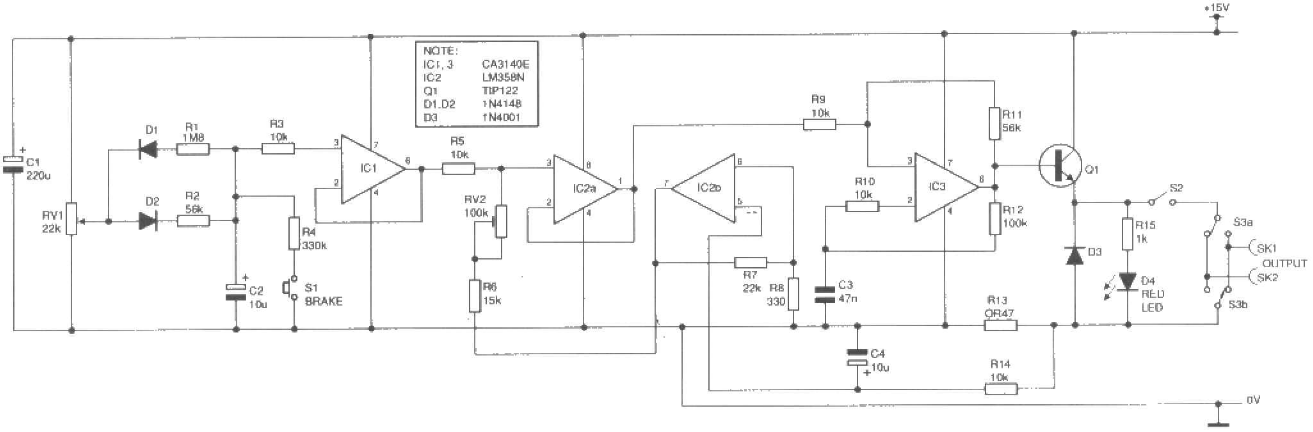


Figure 3: The main circuit of the pulsed train controller

a mixer stage.

A current sensing resistor is included in series with the 0 volt output of the controller. The average voltage developed across this resistor is proportional to the average output current. The pulses across the resistors are fed to a smoothing circuit, and the resultant dc output voltage is then amplified. The amplified signal is then combined with the output of the speed control circuit by the mixer stage. This provides positive feedback which gives the overcompensation effect. Increased output current gives a higher output voltage from the amplifier stage, and this voltage is fed to the input of the pwm oscillator where it produces an increase in the output voltage.

The feedback has to be high enough to give good speed stabilisation, but it must be kept below the point at which the circuit shows a tendency to latch with the output voltage at maximum under heavy loading. The degree of feedback is adjustable, and in practice it is trimmed to the level that gives optimum results.

Circuit Operation

Figure 3 shows the main circuit diagram for the pulsed train controller, and the mains power supply circuit appears in figure 4. Starting with the main circuit, the pwm oscillator is based on IC3. This is used in what is virtually a conventional operational amplifier squarewave generator, but the left hand end of R9 is fed with the control voltage rather than being biased to half the supply voltage. Although this may seem to be a very crude form of pulse width modulation, it actually works very well, and it is certainly more than adequate for the present application.

TR1 is the buffer amplifier, and this is an emitter follower stage. TR1 is a power Darlington device which has an extremely high current gain. Consequently, it can provide output currents of an amp or so from a drive current of less than a milliamp. D3 protects the circuit from high reverse voltages that can be generated across the highly inductive load provided by a dc electric motor. LED D4 is wired across the output via current limiter R15, and its brightness varies in sympathy with changes in the output voltage.

At the minimum speed setting it is possible that the output voltage will not drop right back to zero. This is of no great importance, since the output potential will be too low to produce any movement from the train. However, S2 enables the output voltage to be switched off completely if desired, and it also provides a convenient means of cutting off the output and bringing the train to a rapid halt. The direction of the train is determined by the polarity of the track voltage. S3 controls the polarity of the output voltage, and acts as the direction control.

R13 is the output current sensing resistor, and R14 plus C4 are the smoothing circuit. IC2b acts as the dc amplifier which boosts the current sense voltage, and it is a simple non-inverting type having a closed loop voltage gain of about 66 times. This is about right for trains which consume maximum currents of under one amp. If you have "thirsty" trains which consume currents of up to an amp or so, it would be advisable to either increase R8 to 680R, or reduce R13 to 0R22.

VR1 is the "throttle" control, and it feeds into a simple C-R timing circuit which has C2 as the capacitive element. If VR1 is adjusted for increased speed, C2 charges through D2 and R2 to the new control voltage. This gives a short delay as C2 charges through R2, but only of a second or two. When VR1 is backed off, C2 discharges through D1 and R1. The value of

R1 is quite high, giving a long discharge time. In fact it can take over half a minute for the train to go from full speed to a halt if the "brake" is not applied. S1 is the "brake" switch, and when operated this provides a lower resistance discharge path through R4. This is sufficient to stop the train from full speed in a few seconds, provided, or course, the "brake" control is backed off first!

The mixer stage is a simple passive type which is comprised of R5, R6, and VR2. The latter enables the degree of overcompensation to be controlled. IC2a acts as a buffer stage between the mixer and the input to the pwm oscillator.

The mains power supply circuit (figure 4) is a conventional regulated design. It provides 15 volts rather than 12 volts, since there are voltage drops in the controller circuit which give a maximum output voltage that is about three volts less than the supply voltage. T1 provides isolation and a voltage step-down, and D5 to D8 give full-wave bridge rectification. C5 is the smoothing capacitor, and IC4 is the voltage regulator. A one amp regulator is sufficient for many model trains, but some locomotives draw slightly more than an amp at full speed and when heavily loaded. A two amp regulator has therefore been specified for IC4. The regulator chip incorporates foldback current limiting which gives a short circuit current of 500 milliamps. This protects both the controller and the motor in the event of accidental overloads. Fuse FS1 provides further protection against overloads.

Construction

Refer to figure 5 for the printed circuit board component layout. The CA3140E used for IC1 and IC3 has a PMOS input stage, and consequently requires the standard anti-static handling precautions to be observed. The LM358N used for IC2 is not a MOS device, but it is advisable to use holders for all three dil integrated circuits. Note that the specified operational amplifiers are types that will work properly in single supply dc circuits, and that most other devices (741C, LF351N, TL071C, etc.) will not work at all in this circuit.

R13 only requires a power rating of one watt, but it might

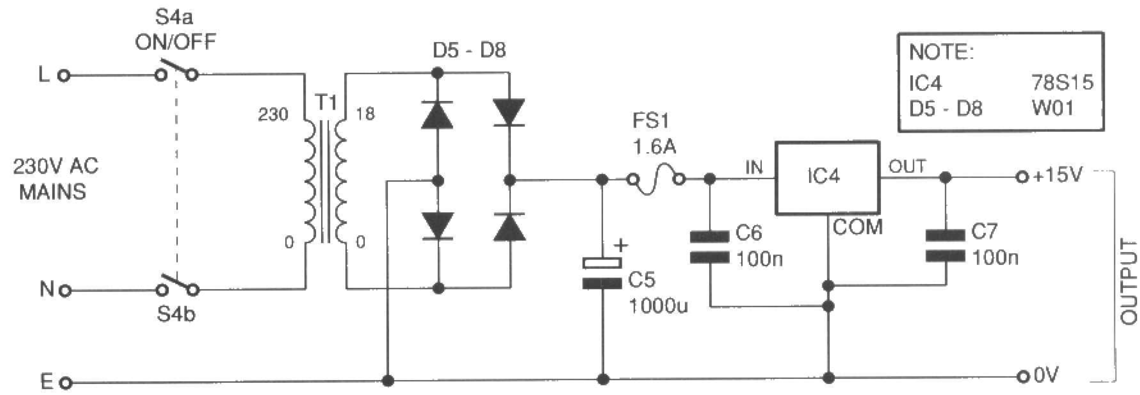


Figure 4: The circuit diagram of the mains PSU

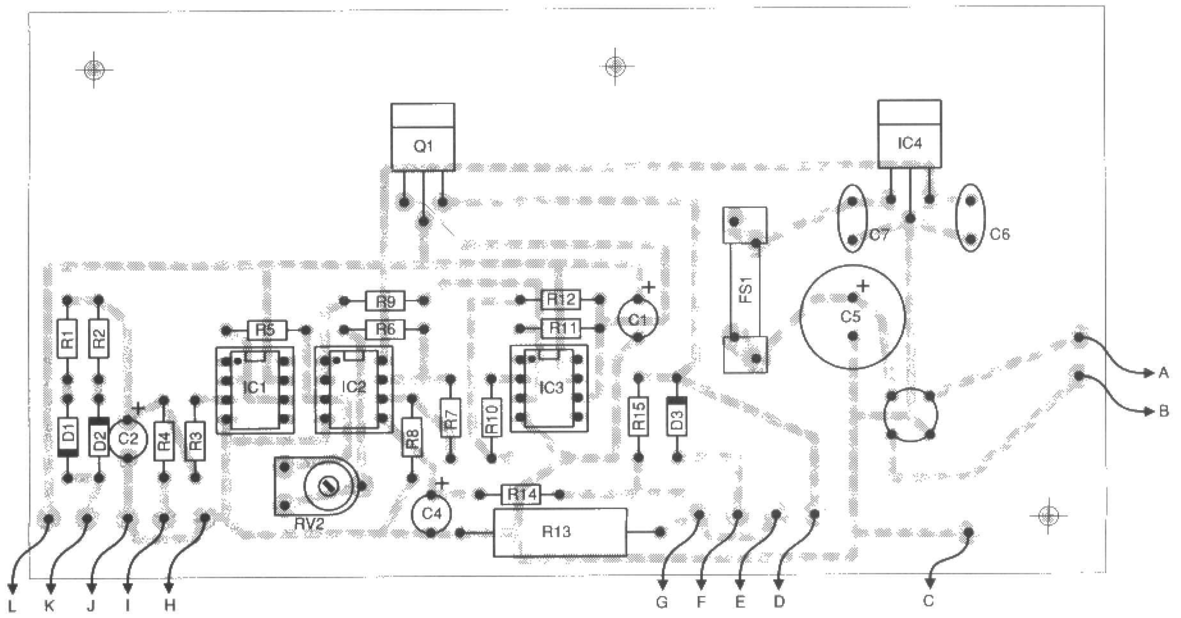


Figure 5: The component overlay for the train controller PCB

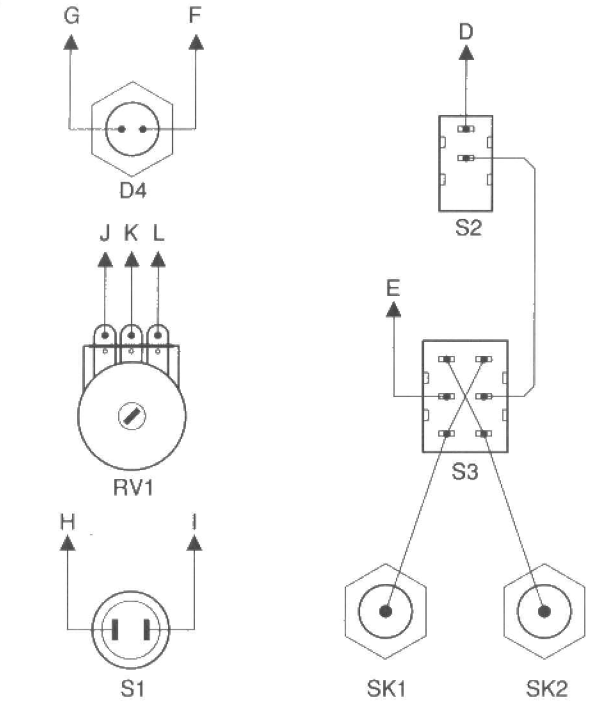


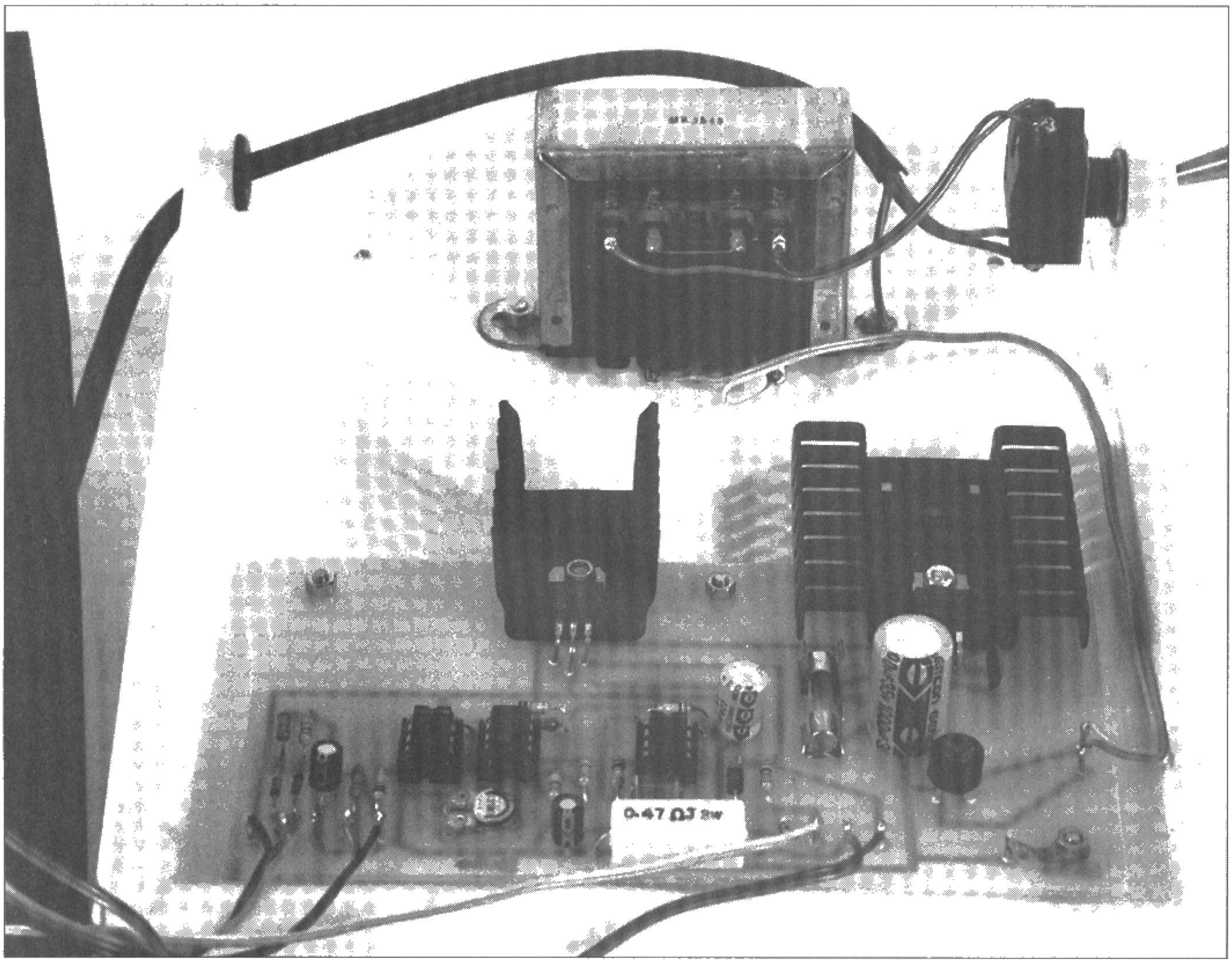
Figure 6: The wiring to the components mounted on the front panel

be difficult to obtain a one watt resistor having a value as low as 0R47. There is sufficient space on the board to accommodate a three watt wire-wound resistor, which probably represents the most practical choice. Fuse FS1 is mounted on the board via a pair of 20 millimetre fuse-clips. The Maplin "Type 1" fuse-clips are suitable, as is any other type which has the correct pin configuration.

TR1 does not have to dissipate much power due to its switching mode of operation. However, it still requires a certain amount of heatsinking in order to guarantee safe operation. A bolt-on TO220 vaned heatsink having a rating of 9.9 degrees per watt is adequate. IC4 has to dissipate slightly more power, but it does not require a large heatsink. A bolt-on TO220 heatsink rated at 6.5 degrees per watt will suffice. Bolt the heatsinks and the power devices to the board, rather than just leaving them flapping around.

In other respects construction of the board offers nothing out of the ordinary, but be careful to get the bridge rectifier (D5 to D8) round the right way. Also make sure that the electrolytic capacitors are fitted with the correct polarity, especially C1 and C5. Mistakes here could cause costly damage. Single-sided solder pins are fitted to the board at the points where connections to the controls, T1, etc. will eventually be made.

Traditionally, train controllers are housed in sloping front cases. A case of this type is a practical choice as it enables the controls to be easily seen and used. As this project is mains powered the case should be of all-metal construction, and it must be earthed to the mains earth lead. The prototype is housed in a sloping front case which has a base size of 165



by 211 millimetres, and a maximum height of 76 millimetres. This comfortably accommodates everything, with no cramping of the controls on the front panel.

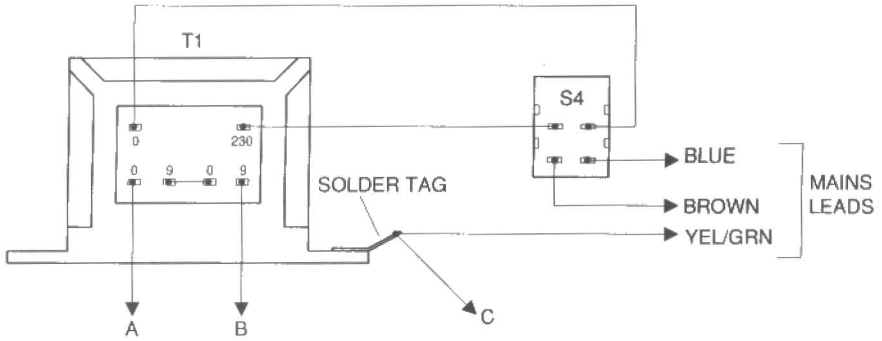


Figure 7: The power supply wiring

Mains transformer T1 is mounted on the base panel of the case, well towards the rear where the case has sufficient height to accommodate it. A solder tag is fitted on one of T1's mounting bolts, and this provides a convenient means of connecting the case to the mains earth lead. On/off switch S4 is mounted on the right hand side of the case, close to T1. The component panel is mounted on the base panel of the case, towards the front of the unit. It is held in place using 6BA or metric M3 screws, with spacers being used to hold the board about six millimetres clear of the case.

The remaining controls, output sockets, and D4 are mounted on the front panel using any layout that is reasonably practical. The hard wiring is then added. Figure 6 shows the wiring to the components mounted on the front panel, and power supply wiring appears in figure 7. Point "C" on the printed circuit board can be earthed to the tag on T1 (as shown in figure 7), or it can be connected to a solder tag mounted on one of the board's mounting bolts. The cathode lead of D4 should be indicated by this lead being slightly shorter than the anode lead.

T1 should have an 18 volt secondary rated at 1.5 amps or more. Most modern mains transformers have twin secondary windings, which means that T1 will probably have to be a type which has two nine volt secondaries rated at 1.5 amps or more, with the two windings connected in series. Figure 7 shows the wiring for a twin nine volt transformer. Take due care with the wiring to S4 and T1 because mistakes here could cause costly damage, and could also be very dangerous. Mains powered projects are definitely not suitable for beginners.

In Use

Start with VR2 set well in a clockwise direction. The controller should then give excellent results, with good starting performance and no tendency for the train to stall at very low speeds. Finding the best setting for VR2 is a matter of trial and error. Adjusting it in a counter clockwise direction will increase the degree of overcompensation, but this does not necessarily mean that it will give improved results. Over doing the overcompensation can result in the controller taking over, and VR1 not exercising sufficient control over the train's speed. Experiment a little with settings for VR2, and try not to be overzealous with the amount of overcompensation.

Opinions differ on the ideal time delays in this type of speed control circuit. They are easily modified if you do not like the suggested delays. The values of R1, R2, and R4 respectively control the momentum, inertia, and braking times. In each case the value of the resistor is proportional to the time delay. As an example, if you wanted to reduce the braking time by 50 percent, the value of R4 would have to be halved to 165k. In practice the nearest preferred value of 160k would be near enough. If you would prefer a straightforward speed control with no delays, omit D1, D2, R1 to R4, C2, and S1. Fit link wires in place of D1, R1, and R3.

PARTS LIST For the PWM Train Controller

Resistors

(all 0.25 watt 5% carbon unless noted)

R1	**1M8**
R2,R11	**56k (2 off)**
R3,R5,R9,R10,R14	**10k (5 off)**
R4	**330k**
R6	**15k**
R7	**22k**
R8	**330R**
R12	**100k**
R13	**0R47 1 watt**
R15	**1k**

Potentiometers

VR1	**22k lin rotary carbon**
VR2	**100k min hor preset**

Capacitors

C1	**220u 16V radial elect**
C2,C4	**10u 25V radial elect (2 off)**
C3	**47n polyester**
C5	**1000u 35V radial elect**
C6,C7	**100n ceramic (2 off)**

Semiconductors

IC1,IC3	**CA3140E (2 off)**
IC2	**LM358N**
IC4	**78S15 15V 2A positive reg.**
TR1	**TIP121 or TIP122**
D1,D2	**1N4148 (2 off)**
D3	**1N4002**
D4	**Red panel LED**
D5-D8	**W01**

Miscellaneous

S1	**Push-to-make pushbutton switch**
S2	**SPST min toggle switch**
S3	**DPDT min toggle switch**
S4	**DPDT toggle switch**
T1	**Standard mains primary, 18 volt 1.5 amp secondary (see text)**
FS1	**1.6 amp 20mm quick-blow fuse**
SK1,SK2	**4mm sockets**

Sloping front metal case, printed circuit board, control knob, TO220 bolt-on heatsinks (see text), 8-pin dil holder (3 off), pair of 20mm fuse-clips, mains lead and plug, wire, solder, etc.

Review

The Electronics Service Manual

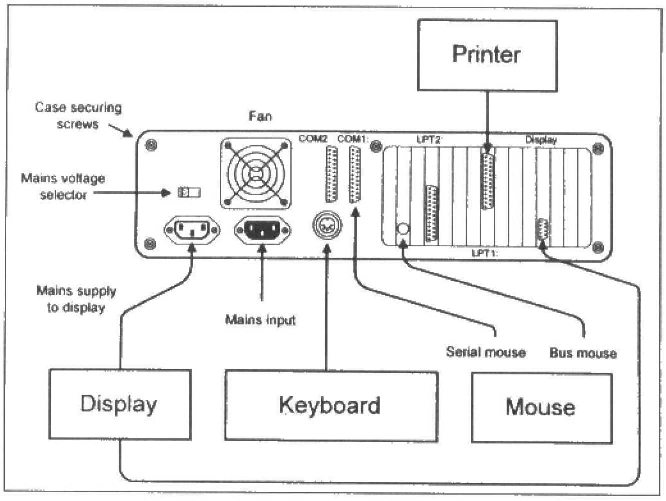
Edited by Mike Tooley
Wimbourne Publishing £39.95
Supplements each £23.50

One certain way of assembling information on electronics without losing pages is to file it in a ring-backed binder. This format is behind the Electronics Service Manual, which is built upon an 840-page basework with supplements currently added every couple of months.

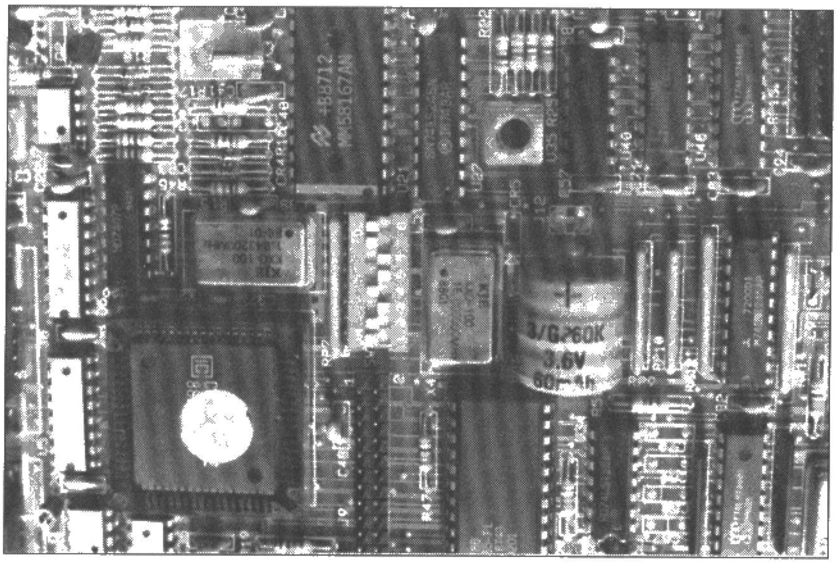
In contrast with Wimbourne's even more substantial Modern Electronics Base Manual, the Electronics Service Manual is focused on servicing and repairs, rather than project-building. Like the MEBM, however, it starts at a level that anyone with reasonable basic arithmetic can follow from scratch. Not that this publication sets itself up as an educational volume, and the opening section Using the Manual advises; "The Electronic Service Manual is not a book which has been designed to be read from cover to cover ...", but it is a giant repository of information, laid out concisely, starting with fundamentals and working towards practical applications by degrees.

Theory to fault finding

The whole manual covers a range of information, from electronics theory and formulae to fault finding techniques and administration of repairs. It is arranged in parts A (Safety) to I (Index), passing through Understanding, Practical Skills, Tools and Test Equipment, Servicing Techniques, Technical Notes, Reference Data and Useful Addresses on the way. The basework as first issued covered mainly basic knowledge and techniques. Knowledge and techniques pertaining to individual classes of equipment kicked in with B9 (Understanding audio) B11 (Understanding video) and F2 (Impact dot matrix printers) in Supplement 1. The base manual, however, now includes the most recent supplement free, giving the user a practical window into repairing from the start. Some topics are covered in the basework, some in the supplements, and some in both. The supplements both extend and update the coverage.



A drawing from base section F1.5 of the Technical Notes



A photograph from base section F1.4 of the Technical Notes

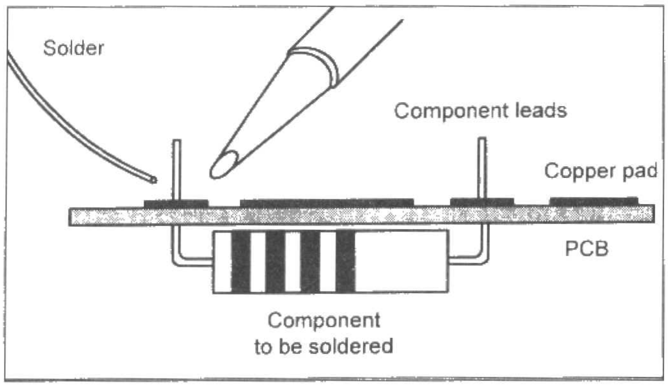
Part A covers safety, first aid, and employers' responsibilities under the Health and Safety at Work Act. Someone setting up a business often knows more about business than legislation. This section raises a number of useful points, some of which might otherwise be overlooked. This is a jumping-off point: the person setting up a workshop must then establish how health and safety information can be updated from local government sources. The section on electrical safety pinpoints a number of hazards.

Part B, which in our review copy with Supplements 1, 2 and 5 comprises about half the manual, is effectively a course on basic electronics. It includes formulae for simple linear circuits, for example, the impedance of an LCR circuit. It starts by defining electrical units, and goes on via other basic information to electromagnetism and magnetic fields by section B1.14.

Accessible

This part starts with the calculation of the magnetic field around a wire carrying current, and the force between two wires carrying current. In the basework this is only two sides, but in that space the basic information on the subject is presented clearly and accessibly.

The related section, B1.15, covers magnetism in iron and other magnetic materials. Again, the relevant information is clear and easy to identify. Magnetism is often poorly understood, and these sections convey the basics in a more accessible manner than the other main source of such



A drawing from base section C1.3, Making soldered joints

information, academic textbooks.

Kirchov's laws are often covered in first year university lectures: in section B2.1 they are explained, with reference to practical examples. One such example is of a battery being trickle charged while running a load and a power-on indicator, something likely to be encountered in life, not only in textbooks.

Surprises

I was surprised to find in the capacitance section an example of calculating the plate area required for a given capacitance with a particular dielectric. This is more basic information than would be needed for repair work, but it is valuable for a deeper understanding of the subject.

Paradoxically, section B2.7 covering transistors shows the basic layered structure of a transistor, but does not mention the depletion region or describe how a transistor functions. Both bipolar and field effect transistor characteristics and biasing are covered, as are basic single stage amplifier circuits and operating conditions. The transistor characteristics shown are somewhat idealised, which is reasonable as the principles rather than the smaller details are highlighted.

Bipolar transistors are again covered in B2.7, but here the diagrams show the cross section of a planar transistor, the type made most widely at present. Typical transistor characteristics are shown, and there are examples of biasing calculations.

This section includes good basic information on many subjects, and in these areas should be a useful reference source. It seems strongest in the areas of magnetism, basic electrical theory, and formulae relating to passive components.

Jumping around

In some areas I found that I was looking for things I could not find: for example, the digital section does not mention Boolean algebra. Of course, this is not necessary for repair purposes as such, but neither is a lot of the other useful basic theory covered. The arrangement of subjects in the later parts of B jumps around a bit for my taste: section 10.7 covers superhet receivers, 10.8 covers rf amplifiers rather well, followed by mixers and local oscillators in their own parts until section 10.11, which covers double superhet receivers (which I would have expected with section 10.7). Then there are more items of circuitry for receivers, including crystal oscillators, which I would look for with local oscillators. Later, there is a section on microcomputers, including operating systems, and still later valves are covered, again quite well.

The section on colour television arrives in supplement 2, starting from colour principles and covering the important points. Waveform diagrams for PAL four field blanking are provided, as well as specifications for the sync pulse, black porch and so on, that which make up the video waveform. A higher starting level of background knowledge is assumed in this section , but you still don't need to know much that is not in earlier parts of section B. The well set out section on video serves as a reminder of the basics, and a reference for details.

Section B also includes, among other things, analogue and digital ICs, valve amplifiers, radio, television, and computers (not all in the basework). This section can form a valuable reference for anyone involved in electronics, not just repairers.

Section C, Practical Skills, covers such things as soldering, avoidance of static damage to components, and visual identification of component types.

The bit about soldering has drawings of a good joint and several types of bad ones. I would have liked some photos. Desoldering using a solder sucker is described as a means of removing simple components, and a warning issued that removing multi-pin components this way is slow and tedious (it is not added that with plated-through pcbs it can be almost impossible, and that component damage is very likely). The use of desoldering braid is not mentioned in the parts we have. Special desoldering tools are mentioned, but the wide variety of types available is not yet discussed.

Section D, Test Equipment, also covers setting up a workshop (lighting, fire extinguishers, storage etc.), repair dockets, and other useful material.

Section E covers specific servicing techniques, which begin in the Supplements. Supplement 2, for instance, covers audio amplifiers. It explains the function of the components with example waveforms in simple and more complicated audio amplifiers, gives information on the adjustment of high quality amplifiers, and fault finding flow charts. Given the correct circuit diagram and suitable test equipment, you should be able to approach most traditional amplifier faults with this section.

Section F, Technical Notes, is a repository for information about various types of product and hoe they work. The basework includes a certain amount of information about PCs which is not easy for non-professionals to locate - IBM error codes and ISA bus signals, for example. Processor types included range from 8088 to Pentium, so this should assist in fault finding any vintage of PC.

Databook

The basework includes a substantial databook of discrete semiconductors. The Reference Data (part G) includes basic electrical data and pin connections sufficient to estimate the likely function of a device in a circuit, and to choose a suitable replacement if the part is available, though it would be too scanty for most equipment design (which is not, after all, the intention). Part H is a list of manufacturers' addresses, with logos for easy identification - a nice touch.

The Electronics Service Manual is intended to be useful to anyone setting up or working in a repair workshop. Many hobbyists find themselves becoming unofficial repairers for family and friends. The basework (now with one free supplement) costs £39.95 plus £5.50 postage (inland UK) from the publishers. New supplements, typically 160 pages, are sent out every couple of months, priced £23.50 plus p&p, and can be individually rejected or cancelled within 10 days. There is also a 30-day money-back guarantee on the first purchase. The manual comes in a stout wipe-clean red ringbinder, and further binders (which will be needed if you collect the supplements) cost £5.50 plus £3.50 p&p. Supplement 6 will be out by the time you read this. Supplement 5, which we have received, includes a section on surface mount components.

The ETI MicroAmp

Part 2

ETI continues Barry Porter's professional-standard stereo microphone amplifier with the description of the later parts of the circuit.

Having considered the general principles of the MicroAmp and first two stages in last month's episode, I shall describe the next three stages and the PCB layout for the twin channels, along with construction and test details for the whole unit (except for the power supply) this month.

M-S decoding

If you have never heard of M-S microphone techniques, stand by for an encyclopaedic treatise in two paragraphs. If you know about M-S operation, skip the next bit in case you rupture yourself laughing!

Stereo recording using two coincident microphones is normally termed X-Y. This technique uses two identical directional microphones arranged at equal offset angles to the recording axis, and is often referred to as "crossed pair" or Blumlein recording.

M-S (middle and side) uses coincident microphones, but of different types. The M microphone, which may have a cardioid, supercardioid or even omnidirectional characteristic, is aimed along the recording axis. The S microphone, which must be a bi-directional, or figure-of-eight type, is set so that its positive side faces 90 degrees to the Left of the recording axis, and hence its negative, or reverse side points 90 degrees to the right. The outputs of the M and S microphones may be converted into a stereo, X-Y signal by means of a sum and difference matrix having the following characteristic:

$$L = M+S$$
$$R = M-S$$

The character of the resulting stereo reproduction depends upon a number of factors, such as the directional performance of the M microphone, level of the S channel relative to the M channel, frequency response of the two microphones and in particular any difference between them.

For a somewhat more detailed discussion of M-S techniques, the Journal of the Audio Engineering Society October 1989 (Volume 37 No.10) has an excellent article by Manfred Hibbing of Sennheiser. (Copies may still be available from Sennheiser UK Ltd. Loudwater, Bucks HP10 8BR Tel 01628-850811, who will also try to sell you some of their excellent microphones, in particular those designed specifically for M-S use.)

Right, so just how do we turn M-S into X-Y (or L and R) signals? Quite easily as it turns out. Starting with two signals termed M and S, we add them together to get the left channel, and we take one from the other to get the right. Figure 6 shows this in diagrammatic form and figure 7 gives the circuit in detail.

It can be seen that the M and S signals are buffered by unity gain stages IC14 and IC15 and are then summed by virtual earth mixing amplifier IC16, giving M+S, with inverter IC18 correcting the phase reversal introduced by the summing stage.

The two signals are also applied to differential stage IC17, the output of which will be the difference between the M and S signals, or S-M to be precise. Inverting stage IC19 turns this into M-S; just what is required for the Right channel.

To obtain an accurate M-S signal, the differential action of IC17 may be adjusted at both low and high frequencies by VR6 and VC3 respectively. To set these, apply a common 100Hz sine wave to the inputs of both IC14 and IC15. While monitoring the output of IC19 with an oscilloscope or AF voltmeter, adjust VR6 for minimum output. Change the frequency to 10kHz and adjust VC3 for minimum output and the job is complete.

For normal stereo (X-Y) operation, the M-S matrix is bypassed. When M-S is selected by switch S10 a warning LED flashes and an audible alarm sounds for several seconds. The reason for this belt and braces approach is that if the M-S matrix is switched in while X-Y microphones are in use, the output will hardly be called "stereo" - possibly "mono plus next to nothing" would describe it better.

If the audible alarm is not required, it can be replaced with a 3k3 resistor, which should be somewhat quieter.

The output amplifier

The MicroAmp outputs should be balanced to allow trouble free operation with both professional and domestic equipment. Because the output stage may be connected to either balanced or unbalanced inputs, it must maintain a constant signal level - in other words, if either of the balanced legs is shorted to ground, the level at the other leg must increase by

6dB to compensate for the missing signal.

The circuit of Figure 8 does this in the following manner: It will be recalled that in order to maintain a 30dB overload margin, the nominal signal level through the MicroAmp had to be -10dBu. The output amplifier has the job of raising this to 0dBu - in other words, it needs to have gain of 10dB. The very action of balancing the output by using two output drivers with a 180 degree phase difference gives an automatic level increase of 6dB, therefore the input buffer amplifier, IC10, needs to have 4dB of gain. In order that the overall unit gain can be accurately set, the gain of IC10 is adjustable with VR4. With the component values shown, this allows approximately plus or minus 2dB of gain adjustment, but feel free to change this to suit your own requirements.

The output of IC10 feeds the two output driver amplifiers, IC11 and IC13, which provide two output signals which are in anti-phase - IC11 inverts the output of IC10, whereas IC13 does not.

While the output is driving a balanced load, no signal will be present at the inverting input of IC12, as it is placed at the null point between two identical signals of opposite phase. If, however, either output is shorted to ground, IC12 comes into action and applies positive feedback around the ungrounded amplifier, increasing its gain by 6dB in the process. (Okay, so the gain should increase by 6.02dB yet in practise it only goes up by 5.95dB, because any further increase will turn the output stage into an oscillator. Stop complaining about 0.07dB unless you can convince me that you can hear it!)

The output balance can be adjusted at both low and high frequencies with VR5 and VC2 as shown in Figure 9. First, using Setup A, apply 100Hz at a suitable level to give an output of +20dBu (7.75V). Then change to Setup B and adjust VR5 for MINIMUM reading. Following this, change frequency to 10kHz and adjust VC2 for MINIMUM reading. Lastly, repeat steps the last two steps until the lowest reading is arrived at.

Phase reversal

Both outputs are equipped with a phase reversal facility - the output legs simply being changed over by relay RL6. In practise this function should never be used, but if you ever come across a lead which has been wired out of phase, or even a microphone which is incorrect, it is much easier to correct this with the press of a button than to get a soldering iron out during a frantic recording session. You may also find it interesting to change the overall phase by reversing both channels. In some circumstances, this can have a marked effect on the sound quality.

Muting

Output muting is another feature that is unlikely to get much use, but if it is missing everyone will complain, so there it is. It operates by grounding the outputs immediately before the output connector, this being carried out by relay RL7 which is operated by switch S9.

Switching functions

Without much doubt, the most common cause of problems in audio equipment are switches that don't (switch that is). Unless you are prepared to pay for aerospace-grade components, an alternative to the ordinary switch has to be found, particularly when switching low level audio signals where dodgy contacts can lead to speaker destroying clicks or difficult to detect distortion.

Some form of solid-state switching would appear to be the answer, but so far all the switching chips tried have fallen short of the ideal. They are adequate for handling signals at low level such as at virtual earth points, but cannot cope with a +22dBu (10V) signal without increasing distortion to an unacceptable level. It seems that nothing can beat a good metal to metal contact, especially if it can be kept away from the air that we so cheerfully breathe. The obvious answer is a sealed relay, and this is the course chosen for the MicroAmp.

The relay used has gold plated contacts sealed in a nitrogen atmosphere, giving an expected electrical life of more than half a million operations when switching 1A.

The coil resistance of the 12V version of this relay is 1k, which happens to be the value of resistor required to drive an LED at 10mA from a 12V supply. Using the relay coil to feed the

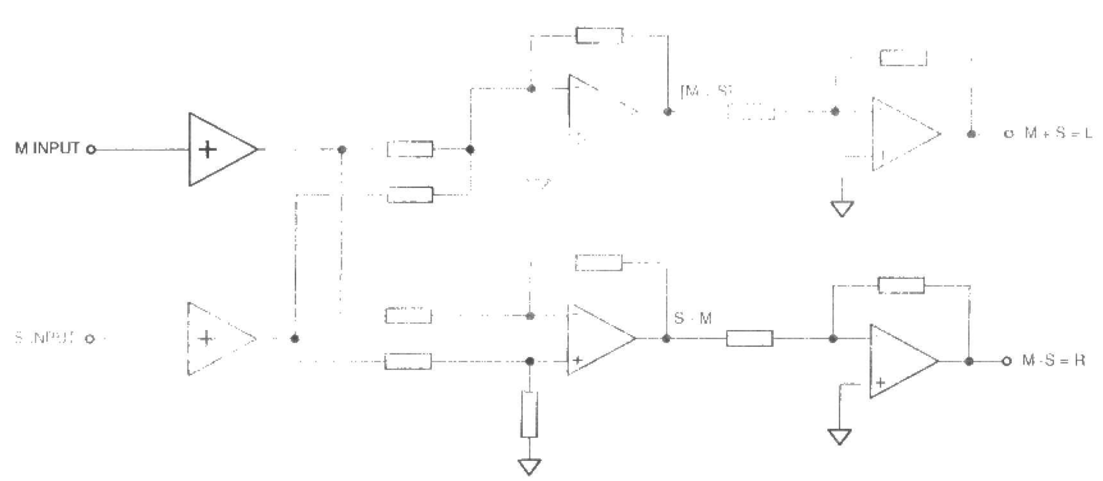
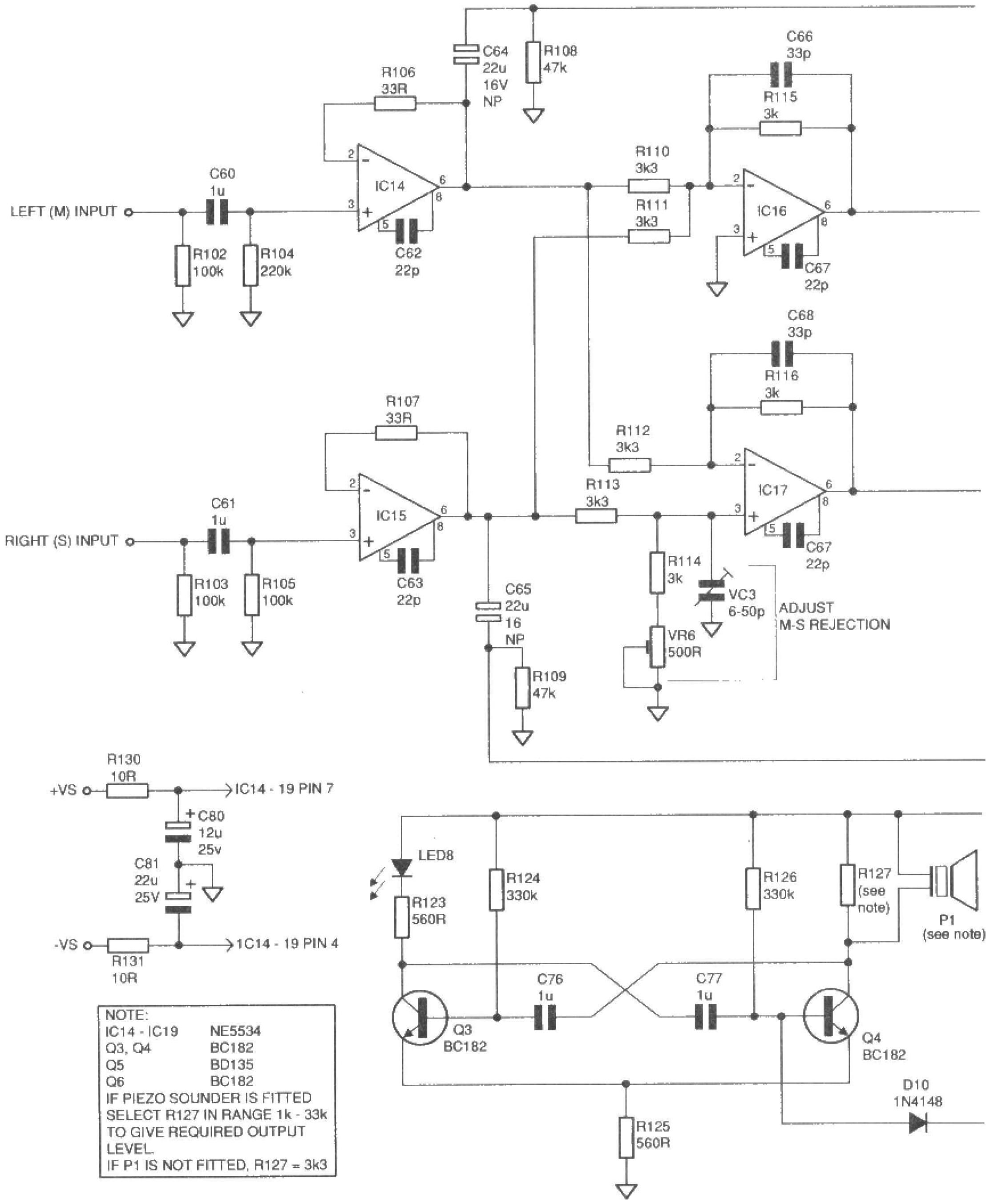


Figure 6: The circuit of the M-S matrix black diagram

Figure 7: The circuit of the M-S decoding matrix



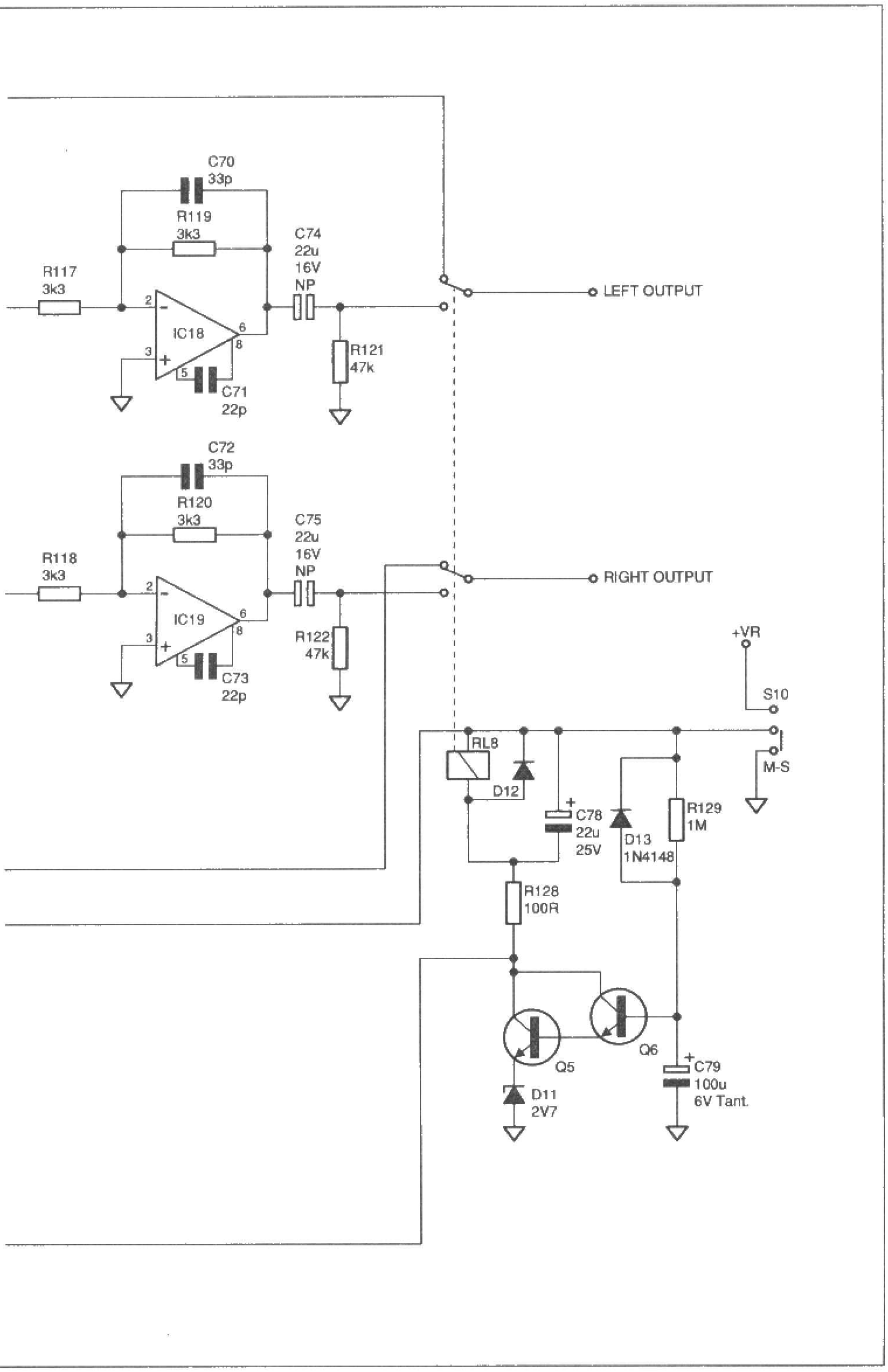
indicating LED has two benefits - it halves the current drawn from the relay power supply, Vr, and it gives positive indication that the relay coil is being driven - no drive to the coil means no LED function.

The system does mean that should an LED go open circuit, the function will not operate, but LED reliability is such that this does not seem to be a problem in practise. Each relay is fitted with a parallel diode (RL2 and RL3 have these built in) to absorb the coil back EMF, and the operation is slugged with a 22uF capacitor and 100R resistor, which eliminates the danger of switching clicks.

All switched parts of the signal path are ac-coupled with series capacitors. It would be nice to produce a unit with fewer capacitors in the path, but this has not proved practical. Some poorly designed mixing consoles are notorious for producing switching clicks, invariably because the manufacturers have cut costs by eliminating most inter-stage coupling capacitors and switching directly at op-amp outputs. Some of the transients generated by this practise have to be heard to be believed - I often wonder if the guilty parties own shares in replacement loudspeaker cone companies.

Some designers use servo feedback systems (feeding back any output dc offset via a high gain integrator) but these have a nasty habit of drifting with changes in temperature. So, the only reliable way to obtain click-free switching is to use isolating capacitors, which is why I have done so.

The rotary switches used for input level and high pass filter



functions also have gold plated contacts, and although not totally sealed, do manage to keep out most air-borne dust and grime. (If you want the ultimate sealed rotary switch, I can recommend one approved by NASA to switch 30A in a pure oxygen atmosphere without exploding - only £250 each!)

Note that the rotary switches should be fitted with "make before break" contacts rather than the more common "break before make", again in the interest of click elimination.

Construction

The complete circuitry for one channel of the MicroAmp is on a single circuit board (Figure 10) and includes the M-S decoding matrix. As only one M-S decoding matrix is required for a two channel unit, it has been placed at one end of the board, and can be removed from the other channel.

The boards should be mounted horizontally, one above the other, with the M-S circuitry on the lower board. This then becomes the right or "S" channel. Signal from the upper, left channel, should be connected to the matrix by two wire links soldered to the pads marked "L".

A stereo MicroAmp can be built into a standard 19-in rack mounting enclosure, 2U (3.5-in) high, using the front and rear panel dimensions shown in Figure 11.

To maintain compatibility with other equipment, 3 pin XLR signal connectors should be used - female for inputs and male for outputs. The pin numbers should correspond to the circuit board, ie pin 1 - 0V, pin 2 - Signal and Pin 3 - Signal.

The power connector may be any suitable type with sufficient pins, but should incorporate a latching system to avoid inadvertent disconnection, which is guaranteed to happen in the middle of an important recording where a re-take is impossible. The RS standard multi-pole is a good choice, as it allows heavy cable to be used, and has proved reliable over many years use.

The MicroAmp in use

Once everything is built, and the power supplies (which will be described in the next instalment of this series) adjusted, the MicroAmp should be plugged in and tested. Make an input dummy load by soldering a 200R metal film resistor between pins 2 and 3 of an XLR-3M plug and replacing the cover.

Initially, make sure that everything is working as intended and that the output signal is clean, clips symmetrically and is free of high frequency oscillation.

The next step is to line up the common mode rejection, M-S rejection, output balance and overall gain as detailed in the individual sections.

Plug the dummy load into the input of one channel, and connect a level meter to the output. Try linking the three power supply earth terminals in various combinations until the quietest is found, being careful that a piece of earthed test equipment doesn't mislead you. If possible, listen to the output through headphones connected to a high gain amplifier (or the ac

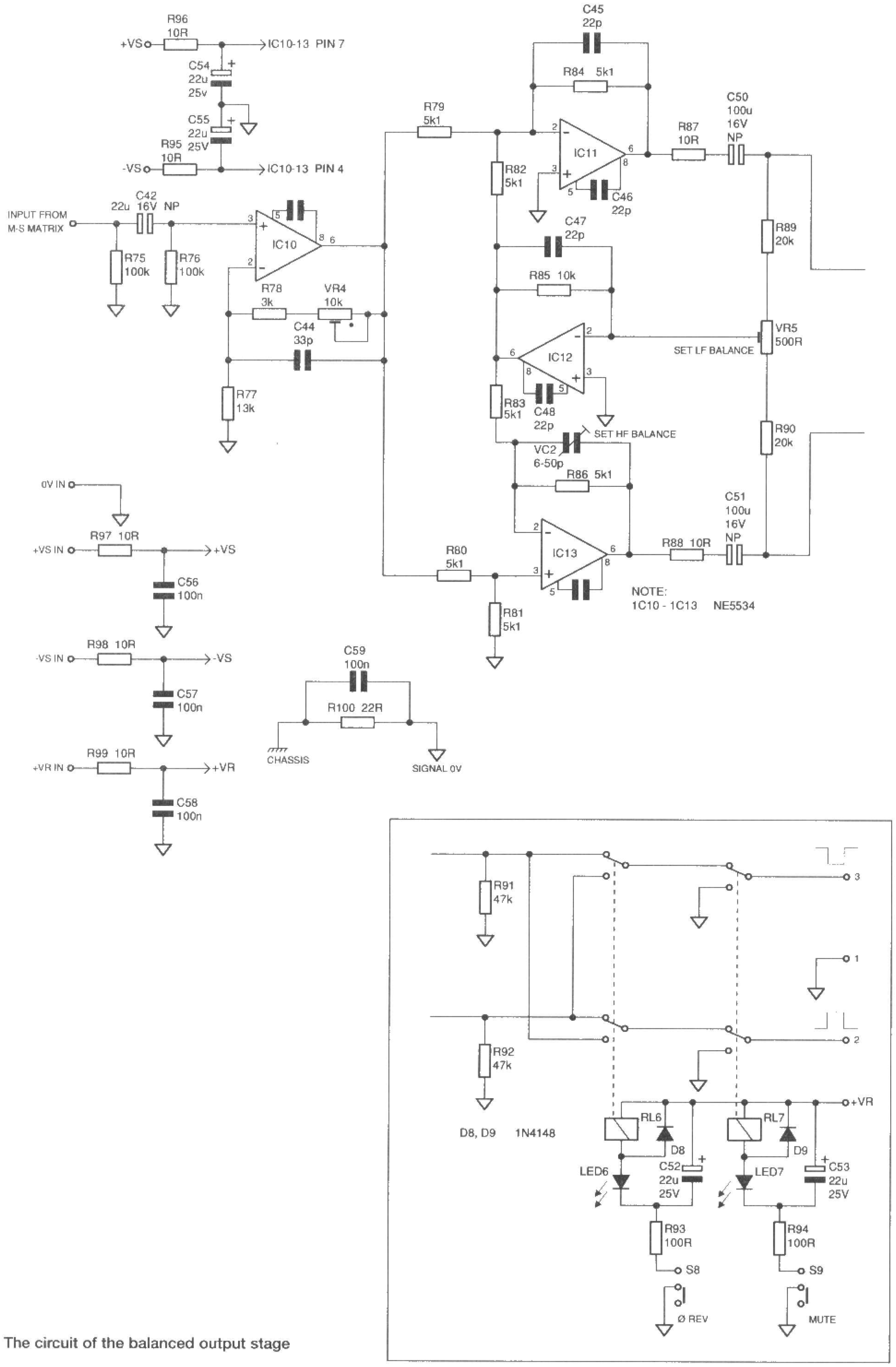


Figure 8: The circuit of the balanced output stage

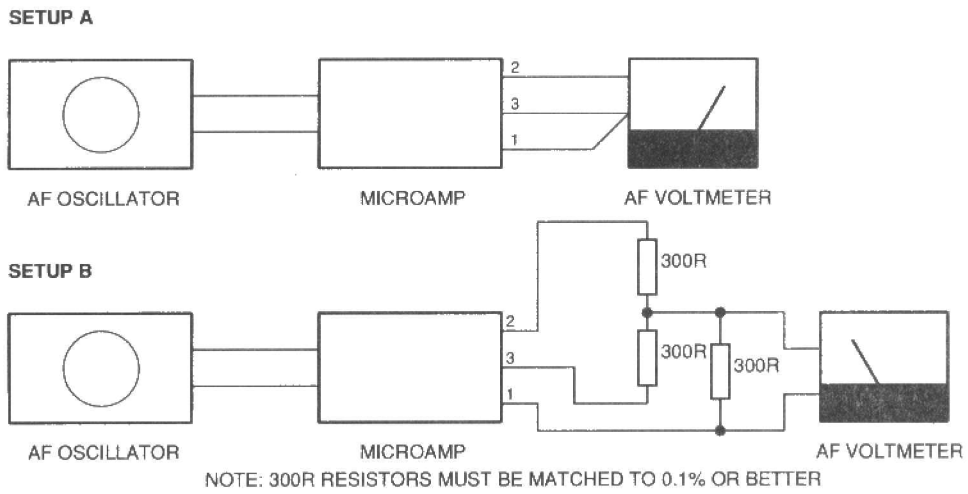


Figure 9: Output balanced adjustment: see text

output of a sensitive level meter) as sometimes two readings may appear to be the same on a meter or scope, yet sound completely different. For example, hiss can often mask hum so that it cannot be measured, but it can certainly be heard.

Once you are satisfied that your unit is as quiet as can be, move your monitoring to the "Insert Send" jack and carry out a measurement of the input noise. With the dummy load in place, switch the input level of the channel being measured to -60dB, set the trim control centrally and measure the output noise via a 22Hz-22kHz DIN weighting filter.

Remember that the input stage has 10dB less gain than it is calibrated at, so if it were noiseless it would measure:

-129.6 + 50 = -79.6dBu

We are looking for an input stage noise figure of 1dB, so the meter should read -78.6dBu, or at least something very close to this. If you cannot get a reading lower than -75dBu, suspect problems. Check the other channel, and if this gives a similar reading it is almost certain that you have an earthing fault, so go carefully over the MicroAmp construction looking for places where the signal 0V may be shorting to the chassis. Have you used jack sockets with isolated sleeve contacts? Is your test equipment really earth free? Does the noise reading improve if you disconnect your 'scope? Is the power supply far enough away? Are you picking up the field of something like a soldering iron transformer? (My soldering iron can introduce hum into a circuit from about two miles away. Can yours?)

Assuming that you eventually achieve a noise figure of 1 or 1.5dB and everything else checks out, you can put your MicroAmp into use.

On the basis that you already have a reasonable amount of recording experience, you should now be able to justify spending next year's holiday money on a few new microphones, and when the wife's GTI needs replacing, don't be afraid to tell her about the new 96-bit recorder you cannot live without.

Expected Performance

Input Noise: 50dB gain, 200R Input load, 22Hz - 22kHz Bandwidth: -77.5dBu
Output Noise: 50dB gain, 200R Input load, 22Hz - 22kHz Bandwidth: -67dBu
20dB gain, 200R Input load, 22Hz - 22kHz Bandwidth: -95dBu
Input Overload: 30dB relative to input level setting
Maximum Output Level: Balanced: +28dBu (19.5V RMS)
Unbalanced: +22dBu (9.75V RMS)
Input Common Mode Rejection: 60dB Gain setting 70dB, 20Hz - 20kHz
M-S Rejection: 60dB, 20Hz - 20kHz
Output Balance: 60dB, 20Hz - 20kHz

Phase Error: Better than ±10 degrees at any setting, 20Hz - 20kHz

Distortion: THD at any gain setting, 20Hz - 20kHz 0.01%
IMD at any gain setting 0.007%

The power supply

We have now covered everything except the important business of how to power the MicroAmp. The next instalment will carry - not one, but two - power supply designs suitable for the Microamp, a basic model and a high-reliability one.

Obtaining parts

Where possible, components have been chosen which are stocked by Electromail Ltd
(Electromail Ltd., PO Box 33, Corby, Northants NN17 9EL
Tel:01536-405555)

Other parts can be supplied by: Audio Solutions Ltd, 9b Ashbourne Parade, Hanger Lane, London W5 3QS Tel 0181 998 8127 Fax 0181 997 0608

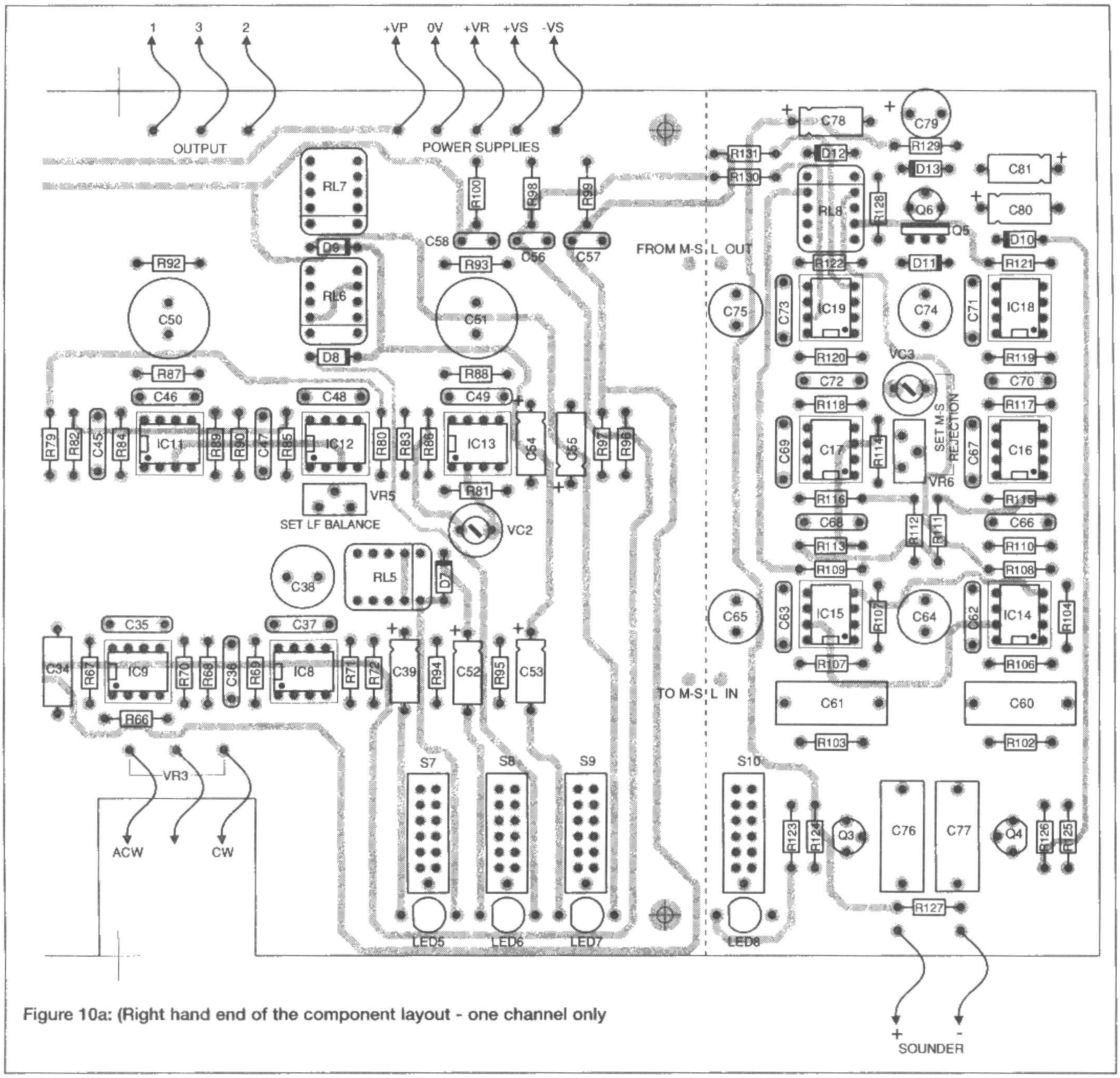


Figure 10a: (Right hand end of the component layout - one channel only

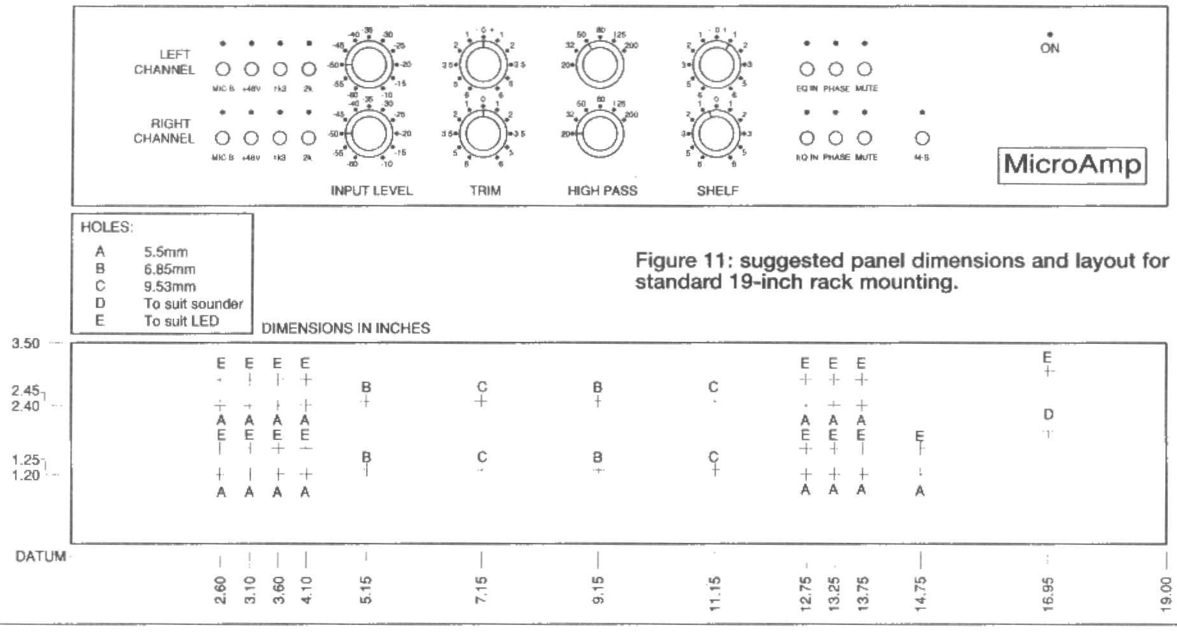


Figure 11: suggested panel dimensions and layout for standard 19-inch rack mounting.

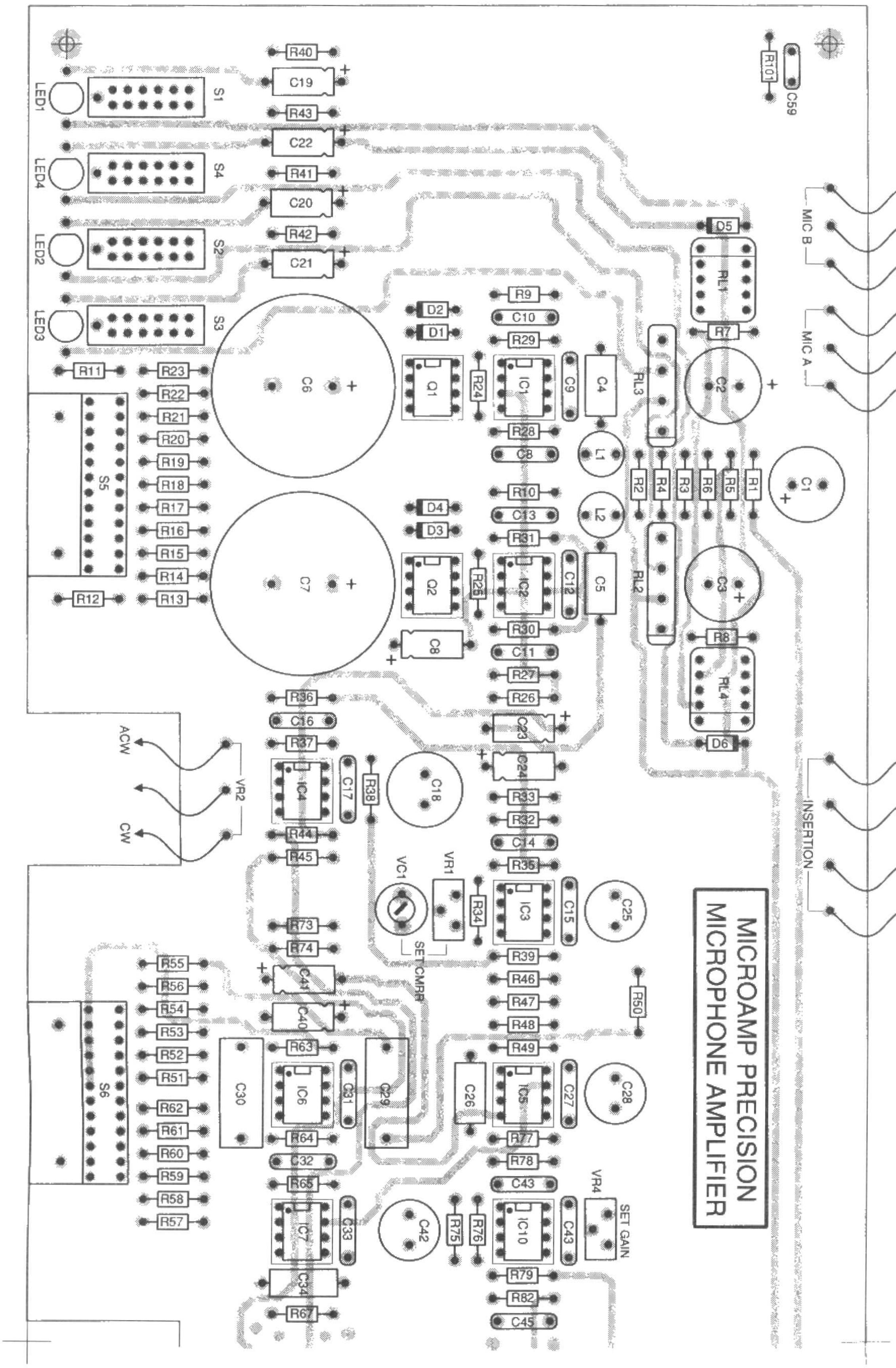


Figure 10b: Left hand end of the component layout - one channel only

EASYGUARD

Terry Balbirnie's simple-to-use, easy-to-make burglar deterrent

This easy-to-use alarm has been designed to protect areas near the house, such as garden sheds, workshops, garages and outbuildings. It may also be used to guard items normally left outside such as bicycles. The system is flexible and the area to be protected may be added to as the need arises.

Battery operated

The battery-operated main unit will probably be sited inside the house. This works in conjunction with a full-size "yelping" type sounder which will be mounted prominently on an outside wall. The unit is connected to remote door and window sensors by means of inexpensive wire which may be of any reasonable length.

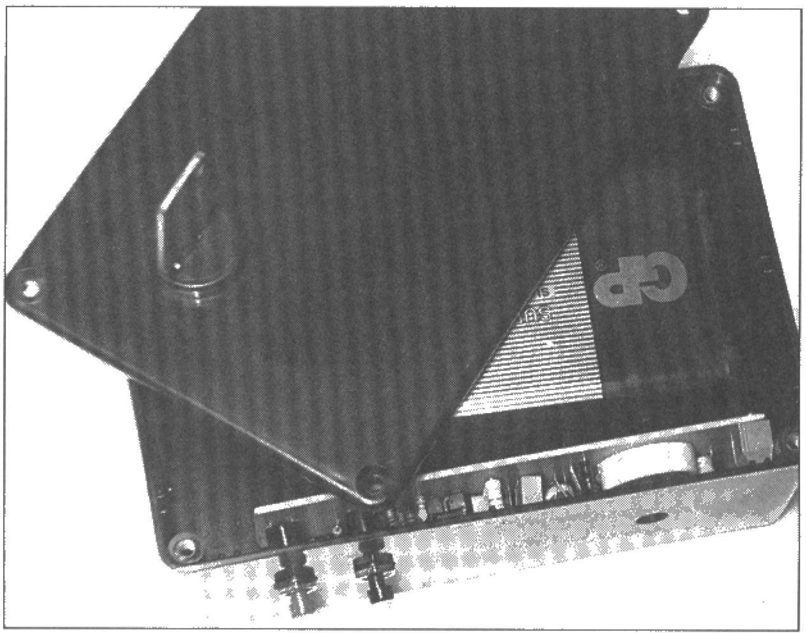
The alarm is switched on and off by means of a key-operated switch on the unit and this prevents inadvertent operation. There is a push-button test switch which may be used to trigger the alarm and a similar reset one to cancel it. The main unit contains a small buzzer which provides a warning when the alarm has been triggered. If this cannot be heard all over the house, there is provision for an additional buzzer or buzzers to be connected remotely. The warning will continue for some preset time up to 1 minute approximately. During this time, the external siren will remain silent. This will allow the alarm to be cancelled if it has been set off accidentally or if it has been triggered for testing purposes. If the circuit is not reset, the siren will operate for 2.5 minutes approximately or some other chosen time. It will not sound again even if the door or window which caused it to operate is left open.

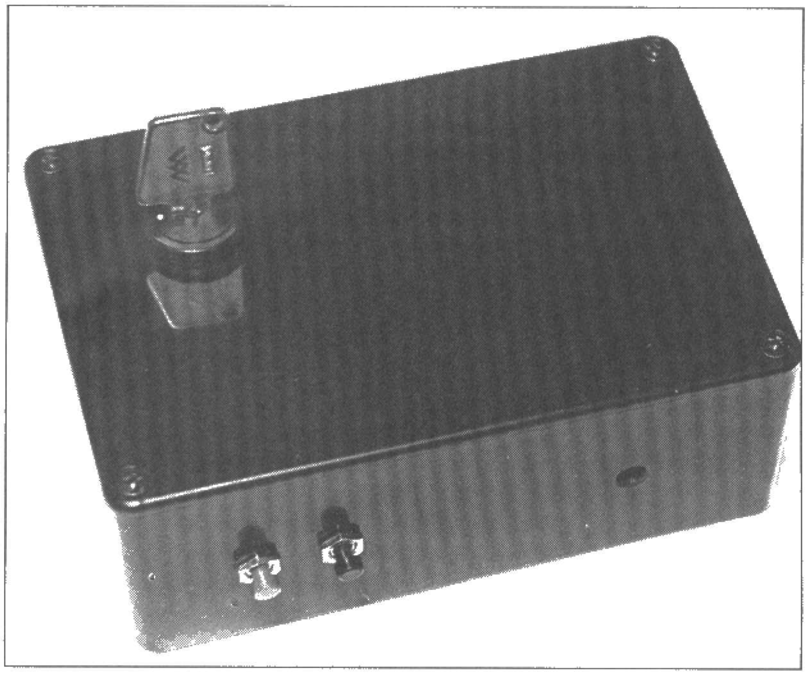
A "panic" button could be sited in some prominent place such as near the front door or in a bedroom. This would enable the alarm to be activated if an intruder was heard. This facility would give peace of mind to the elderly or to anyone living alone.

A bit loopy

Each window and door to be protected is fitted with a magnetic door contact. These may be obtained from any supplier of burglar alarm equipment. They are also listed by many electronics mail order suppliers. The device consists of two parts, a reed switch and a magnet housed in plastic mouldings. The magnet section is attached to the moving part of the window, door, etc. The reed switch is mounted on the fixed part adjacent to the magnet. While the door or window is shut, the reed switch contacts are held closed by the magnetic field and there is no further effect. When the two sections are parted, the contacts open and the alarm is triggered. Even if this only happens momentarily, the siren will sound for the full term or until cancelled at the unit.

Any number of door contacts may be used. These are connected in series to form a continuous loop which is fed back to the main unit. The normally-closed contacts of a panic switch or switches could also be included. Another idea would





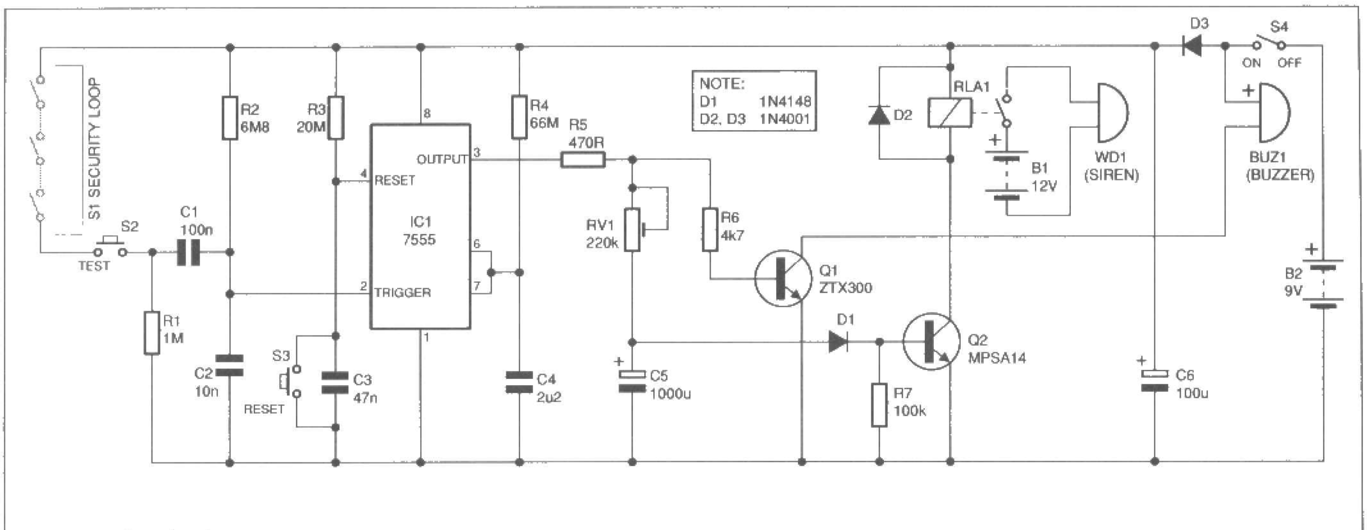


Figure 1: the circuit

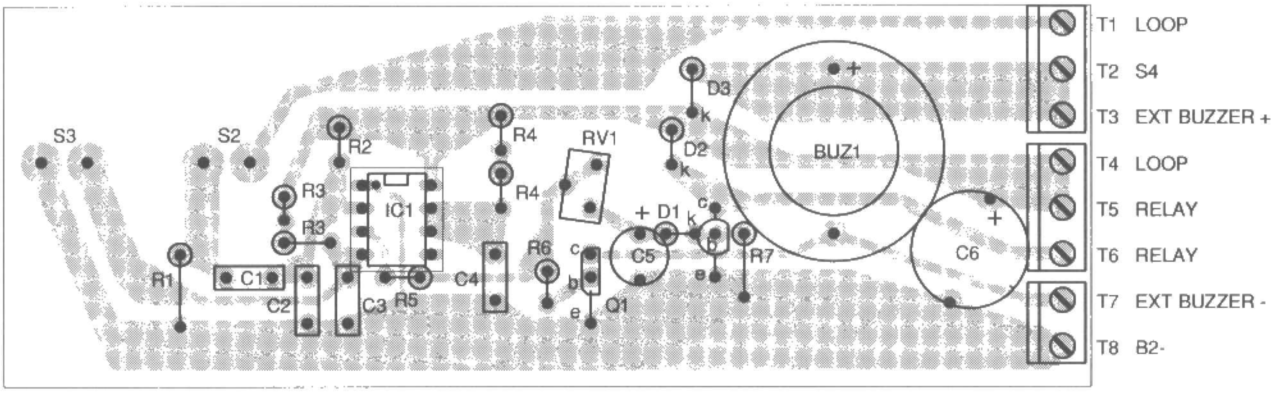


Figure 2: the Easyguard component layout

be to use pieces of connecting wire with plugs and sockets attached. This could be used to protect a bicycle by passing the wire between the spokes of a wheel. Since the wiring between the reed switches is part of the loop, an intruder cutting it will also trigger the alarm.

While the circuit is switched on, the current requirement is only 80uA approximately. The internal 9V battery may be expected to give more than 1 year of service if the alarm has not sounded very often. When the internal buzzer operates, the current rises to about 7mA. When the siren switches on, the current will be some 90mA. The main sounder is powered by its own battery - this will be situated adjacent to the siren itself inside the alarm housing. This battery should last for years since no current is drawn unless the siren is actually sounding.

How it works

The circuit for the EasyGuard alarm is shown in figure 1. Battery, B2, provides a supply when on-off switch, S4 is on. All switches labelled "S1" represent the closed contacts of magnetic door contacts and any other items in the security loop.

The loop and normally-closed contacts of test switch, S2, keep the left-hand side of capacitor C1 high. The right-hand side of C1 is also made high via resistor R2. When the loop is broken, the left-hand side of C1 is suddenly made low through resistor, R1. A low pulse is then transferred to the right-hand side of C1 and this makes IC1 trigger input, pin 2, low momentarily. IC1 and associated components are configured as a monostable which is activated by this pulse. Once triggered, the output, pin 3, goes high for a certain time then reverts to low. If the security loop remains broken, no more pulses will pass through C1 so, once the monostable has timed out, further triggering may only be achieved by re-establishing the loop and breaking it again. The normally high state of IC1 trigger input prevents possible false operation.

Time period

The monostable time period is determined by the values of resistor R4 and capacitor, C4. With the components specified this will be 2.5 minutes, approximately. The value of R4 could be raised in proportion if the timing needed to be increased and vice versa. Capacitor C2 allows random ac signals picked up by the loop wiring and passing C1, to bypass the trigger input and flow to the negative supply line. This also helps to prevent false operation.

IC1 reset input, pin 4, is kept normally high through resistor R3 and this enables the monostable. Once triggered, operation may be cancelled by operating push-to-make reset switch, S3. This makes pin 4 go low for an instant. On powering-up, capacitor C3 charges through resistor R3. Pin 4 is therefore kept low until the capacitor has charged sufficiently to remove the low state. This takes 1 second approximately. The reason is to provide a soft start and this prevents possible self-triggering when the unit is switched on.

With the monostable triggered and IC1 output high, current flows through resistor R5 and some enters the base of transistor, TR1, via resistor R6. This turns the transistor on and collector current flows through low-power buzzer, BUZ1 (and any additional buzzer connected in parallel with it). Current also flows through preset potentiometer RV1 (connected as a variable resistor) and diode, D1, to the base of Darlington transistor TR2. At first, this is held off because the voltage across uncharged capacitor C5, and hence at the base, is zero. However, capacitor C5 charges slowly through R5 and VR1 and the voltage across it rises. When it reaches 2.1V approximately, TR2 switches on.

Warning time

This figure of 2.1V comes about for the following reason. Since TR2 is a Darlington transistor, it really consists of two inter-connected transistors. Each base/emitter junction is equivalent to a silicon diode and 0.7V approximately is needed to make each one conduct. This is added to the 0.7V to make diode D1 conduct - that is, 2.1V in total. The time taken for this to happen will depend on the adjustment of RV1. At minimum setting it will be a fraction of a second and at maximum about one minute. This provides the warning time during which TR2 and the main siren are held off. RV1 will be adjusted as required at the end of construction.

With TR2 on, current flows through the coil of relay, RLA1, and energises it. The "make" contacts then establish a circuit from battery B1 to siren, WD1. Diode D2 bypasses the reverse high-voltage pulse which appears across the relay coil when the current through it is switched off. Without this, semiconductor components in the circuit could be destroyed.

The use of a separate battery supply for the main siren avoids any problems with voltage drop which would occur over long runs of light-duty wire. Also, as the battery in the main unit ages it will continue to power the circuit correctly but would fail to operate the sounder at full power.

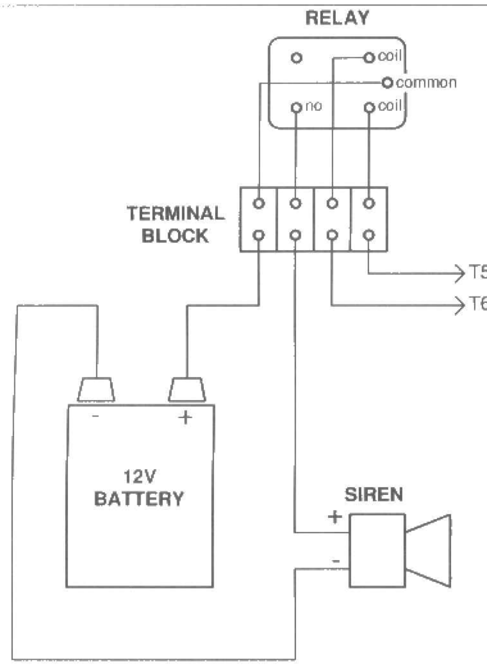


Figure 3: Connecting up the siren

Construction

Construction is based on a single-sided printed circuit board (PCB) and the component overlay is shown in figure 2. Note that all the main unit components, apart from on/off switch S4 and battery B2, are mounted on the PCB. An 8-section piece of screw terminal block (T1 to T8) is used to make all the external connections. In the prototype, switches S2 and S3 were also used to secure the PCB inside the enclosure.

Begin by soldering the terminal block and ic socket on to the PCB in the positions indicated. The terminal block will probably consist of two pieces of three sections and one piece of two. These should be linked together before soldering them in place (look for the small tongue and groove on the side). Add switches S2 and S3. Take care to identify them correctly - S2 has push-to-break contacts and S3 has push-to-make ones.

Follow with all resistors, capacitors, diodes, transistors and the buzzer. Note that the flat face of each transistor points towards the right-hand side of the circuit panel. Take care over the polarity of capacitors C5 and C6, the buzzer (as marked on the body) and the three diodes (the end marked "a" is the anode and is the non-striped end). Note that C5 is mounted flat on the PCB (see photograph) - take care that its end leads do not touch one another and cause a short-circuit. Note also that there are two resistors each labelled R3 and R4. This is to allow high values to be made up using two units connected in series. For R3, two 10M resistors should be used. For R4, use two 33M resistors or as required for the alarm on time. Of course, single resistors could be used instead if the correct values were available. In the case of R4, this would be soldered between the top and bottom holes, ignoring the inter-connected ones in the middle. In the case of R3, it would be soldered in either position linking the holes in the other one with a short piece of wire.

Adjust VR1 sliding contact to approximately mid-track position then insert the ic into its socket with the correct orientation. This is a CMOS component and static-sensitive - to avoid problems, touch something earthed - such as a water tap - first.

Testing

It is more convenient to test the circuit and adjust it before mounting the PCB in the box. Connect the positive and negative battery snap wires to T2 and T8 respectively. Connect a small bulb (say, 6V 0.06A rating) in a suitable lampholder to T5 and T6. This takes the place of the siren relay so that testing may be carried out without disturbing the neighbours. Inter-connect T1 and T4 using a short piece of wire to represent the security loop. Finally, connect the battery. The on-board buzzer and the bulb should both remain off. If the buzzer does sound, cancel it using S3. False triggering could occur if the battery snaps were not connected sharply. Press test switch S2 (to break the loop) - the buzzer should sound. After a short time, the lamp should come on and remain on for about 2.5 minutes. Adjust RV1 for the required hold-off time - anti-clockwise rotation (as viewed from IC1 position) increases the timing. Note that when the circuit is cancelled using S3, the bulb goes off a few seconds afterwards - that is, while capacitor C5 discharges. For this reason, allow one minute between tests or the hold-off time will appear to be too short. The relay may not switch at the same point as the bulb comes on so it may be necessary to re-set the timing when the siren is finally connected. With testing and adjustment complete, remove the wires from the terminal block.

In the prototype, the PCB was arranged vertically in the case. With on-off switch, S4, mounted on the lid. Of course, this arrangement is not critical and will depend on the size and shape of the available box. Drill holes to correspond with switches S2 and S3. Make a further one above the buzzer position. Make a large hole for all the external wires to pass through to the terminal block. Make the hole for on-off switch S4 and mount this. If necessary, make a bracket to secure the battery. However, this will probably stand in the box without further support. Drill holes in the free area of the box (behind the battery position) for attaching it to the wall later.

This might be a good time to think about a suitable site for the unit. If the internal buzzer can be heard about the house, so much the better. It will save on wiring and the need for a remote buzzer. Connect the positive battery snap to one terminal of S4 and the other switch terminal to T2 using a short piece of stranded wire.

Relay arrangements

Identify the tags on the relay used for the coil and normally-open ("make") contacts. Solder short pieces of stranded wire these tags. Secure the relay inside a small plastic box using a little quick-setting epoxy resin adhesive or a small bracket. Attach a 4-section piece of screw terminal block nearby and connect the wires to it. Figure 3 shows a typical arrangement but, of course, this will depend to some extent on the arrangement of tags on the relay.

Attach the alarm housing and secure the siren. Position the relay and battery close to it. A heavy-duty 12V battery should be used. This may consist of two 6V type 918S or similar in series. Connect the battery and sounder in series with the relay normally-open contacts (figure 3). Run a length of twin wire (such as light-duty loudspeaker wire) from the coil connections to T5 and T6 at the main unit (polarity unimportant).

If an additional warning buzzer is needed, mount it inside a small plastic box and drill some holes in the lid for the sound to pass through. Run a length of light-duty twin wire from it to terminals T3 (positive) and T7 (negative). Take care to keep a check of the polarity - if the buzzer is connected incorrectly it will not work. Attach the main unit to the wall in the chosen position.

Making contact

Attach the magnetic contacts on all doors and windows to be protected. When the door or window is closed, only a small gap should exist between the two sections. Connect the reed switches in series using light-duty wire and run the ends of the loop back to T1 and T4 on the unit. If a panic button is used, include its normally-closed contacts as part of the loop. Secure the PCB in position inside the enclosure. If the battery case is made of metal, it may be necessary to use a piece of thin cardboard to insulate the copper track side of the PCB before placing it in position. Connect the supply and attach the lid. Check that all windows and doors protected by the system are closed and switch on. If the alarm self-triggers, press the cancel button. Check the hold-off time under real conditions (it may not be the same as when set previously) and re-adjust if necessary.

It is advisable to operate the main siren for a short time every few months to check the condition of the battery. Remember, it will sound for a few seconds after pressing the cancel button. A good technique is therefore to trigger the alarm and press S3 immediately the siren is heard. The internal battery may be checked every so often by triggering the alarm and cancelling before the main siren operates.

PARTS LIST

For the Easyguard Alarm

Resistors

R1	1M
R2	6M8
R3	2 off 10M (see text)
R4	2 off 33M (see text)
R5	470R
R6	4k7
R7	100k
RV1	220k min. vert. preset

Capacitors

C1	100n min. metallised polyester 5mm pin spacing
C2	10n “
C3	47n “
C4	2.2u “
C5	1000u 16V PCB electrolytic

Semiconductors

IC1	7555 CMOS timer
TR1	ZTX300
TR2	MPSA14 Darlington
D1	1N4148
D2, D3	1N4001

Miscellaneous

S1	Magnetic door contacts as required - see text
S2	Min. push-to-break switch
S3	Min. push-to-make switch
S4	SPST key-operated switch - see text
T1-T8	PCB mounting screw terminal block (2 triple and 1 double) - 5mm spacing.
BUZ1	PCB mounting buzzer 5mA 9V operation
B1	12V heavy-duty battery (or two 6V types)
B2	PP9 battery
RLA1	Relay with 6V 100 ohm coil.

PCB materials. 8-pin dil socket, 4 sections of 2A screw terminal block, heavy-duty siren 12V operation at 300mA approximately. Plastic box size 150 x 100 x 60 mm approx. Light duty twin wire. Small box for relay.

All components for the EasyGuard are available from Maplin (see back cover). 33M resistors are listed as "high voltage" resistors. The siren was the "Staccato Electronic Sounder".

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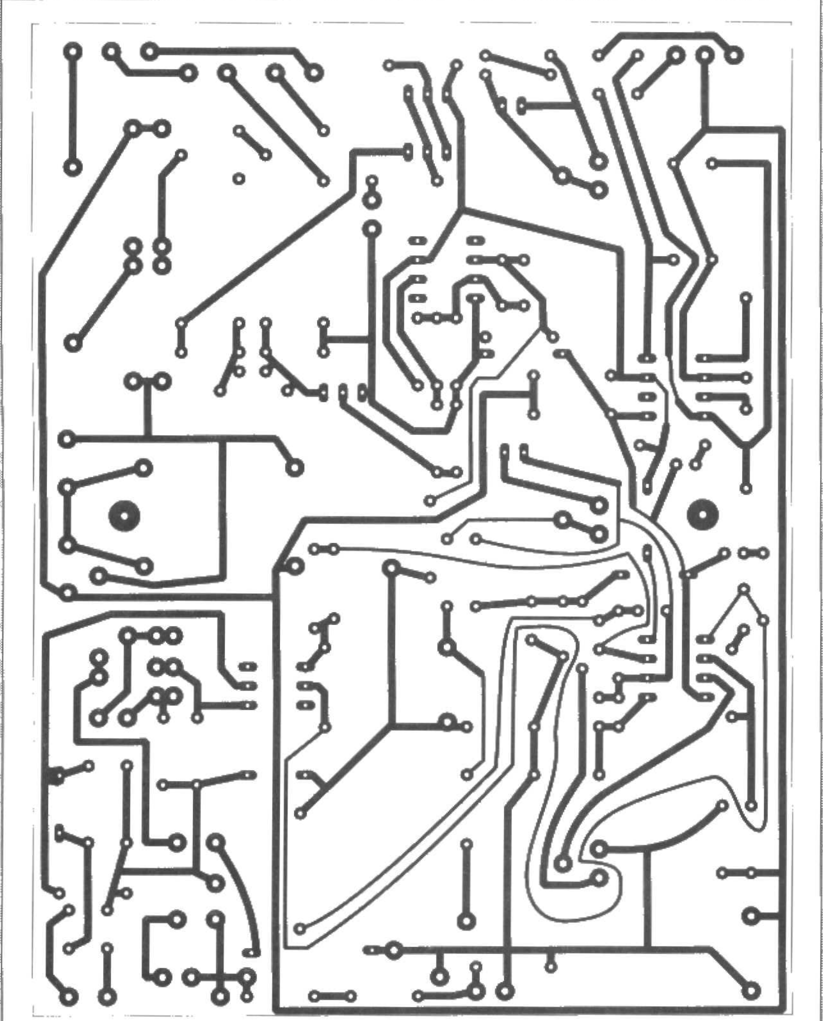
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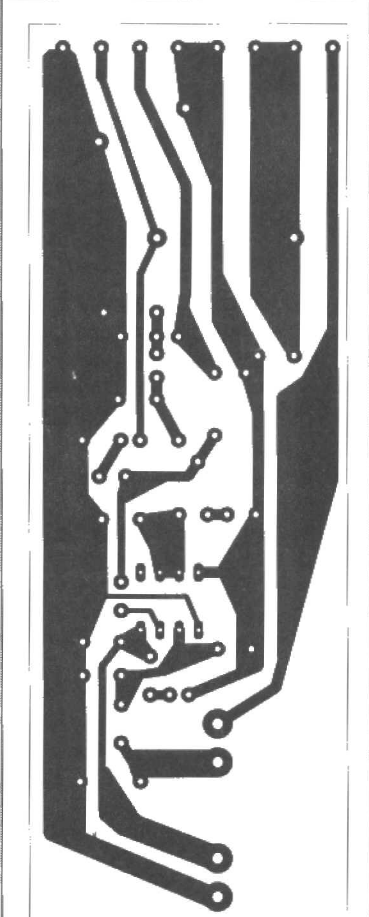
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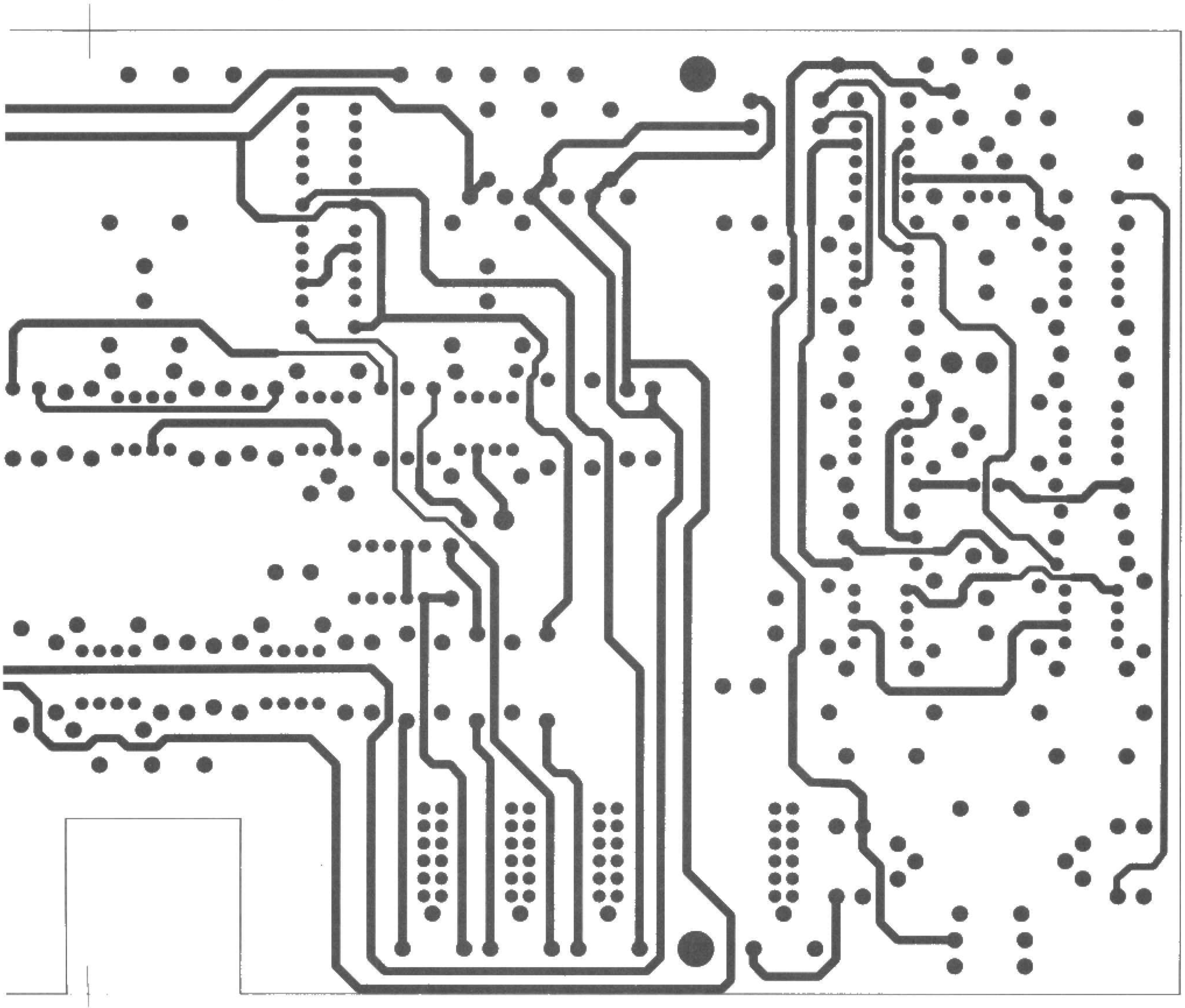

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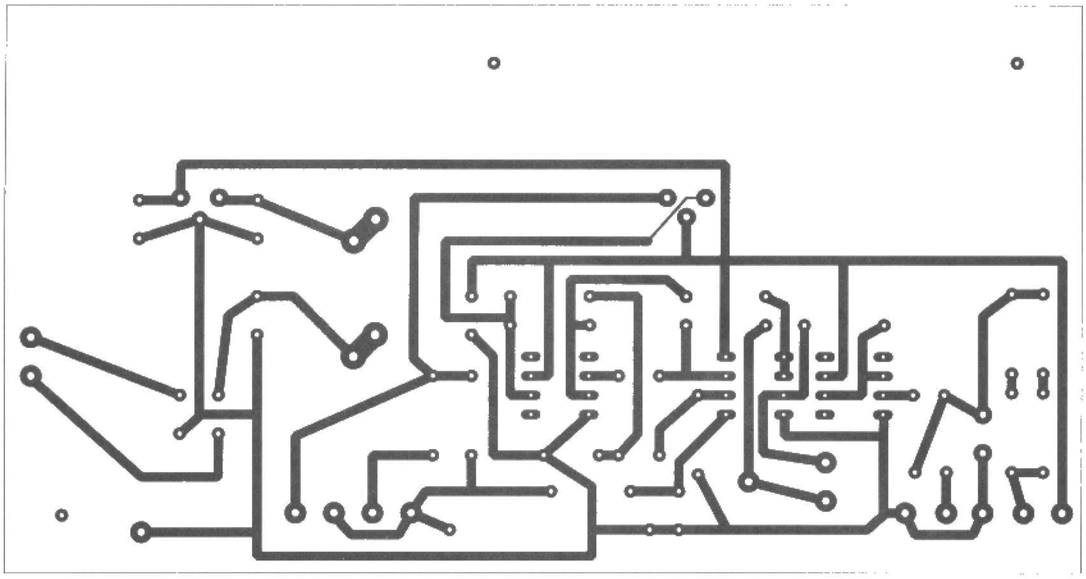

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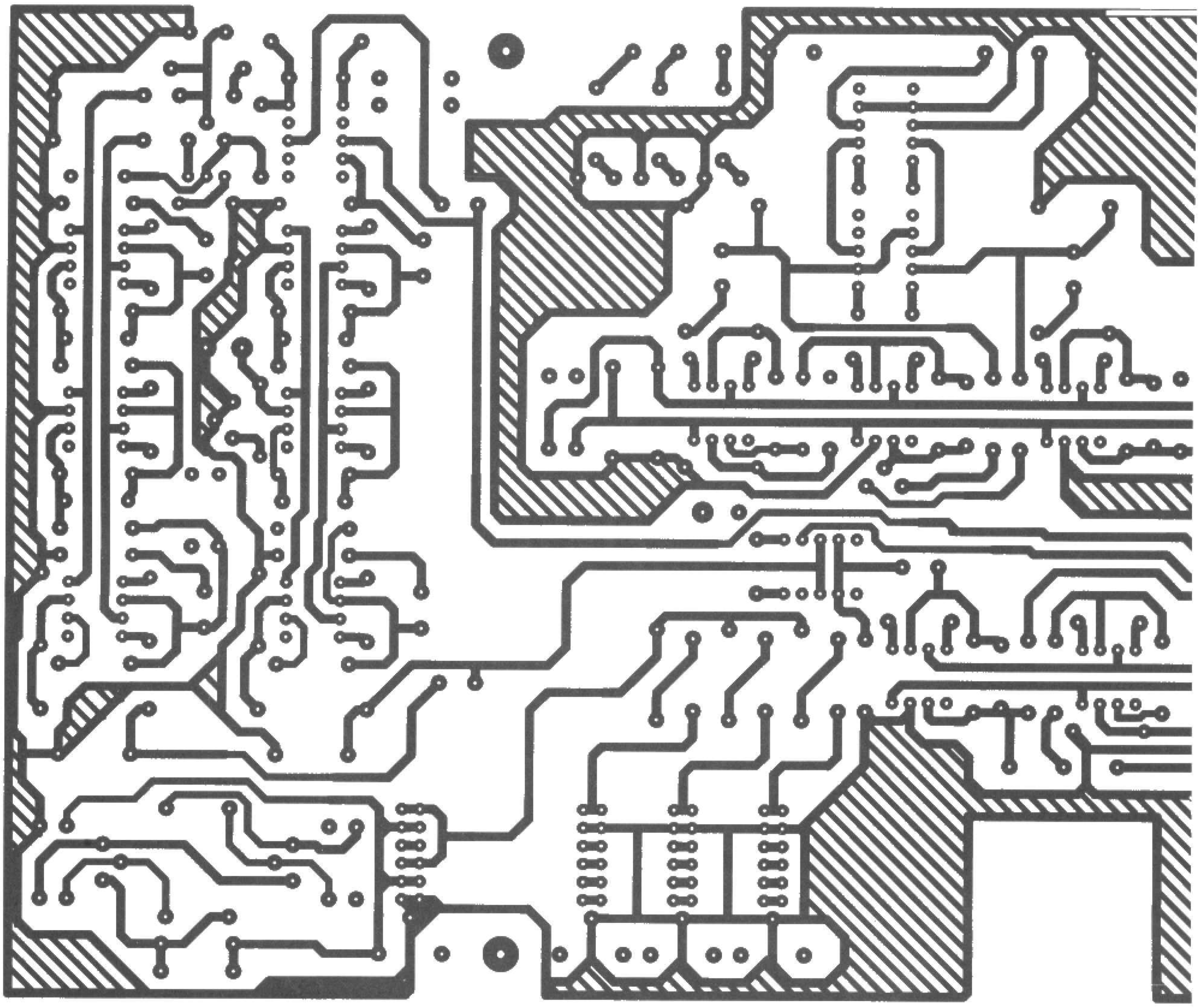

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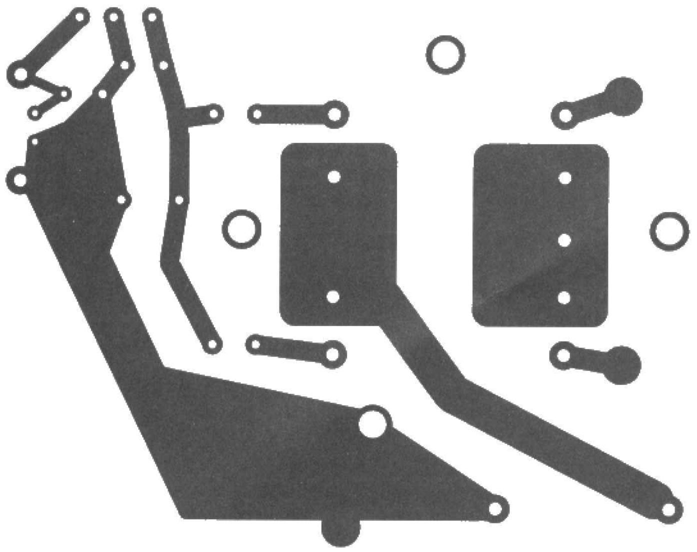
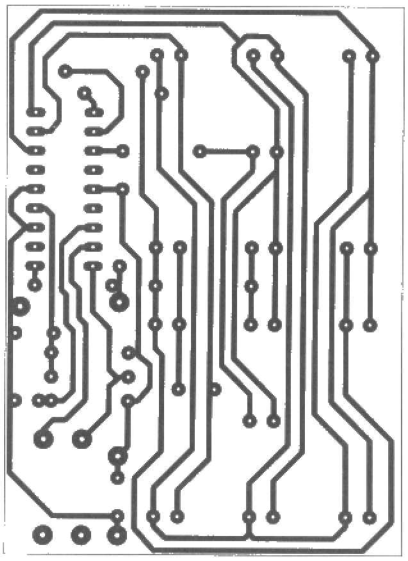


MAINS OP LIGHTER SOCKET



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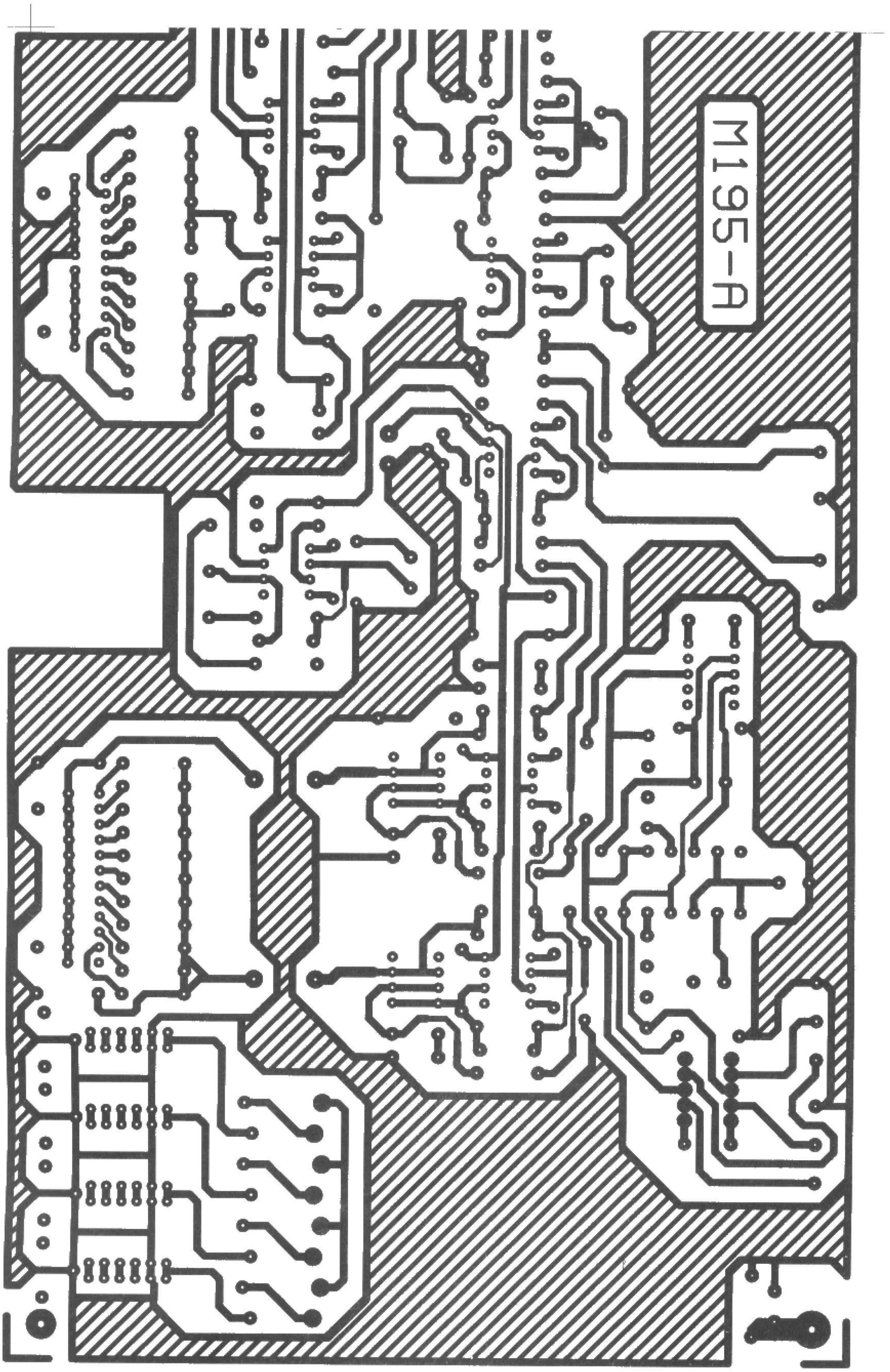

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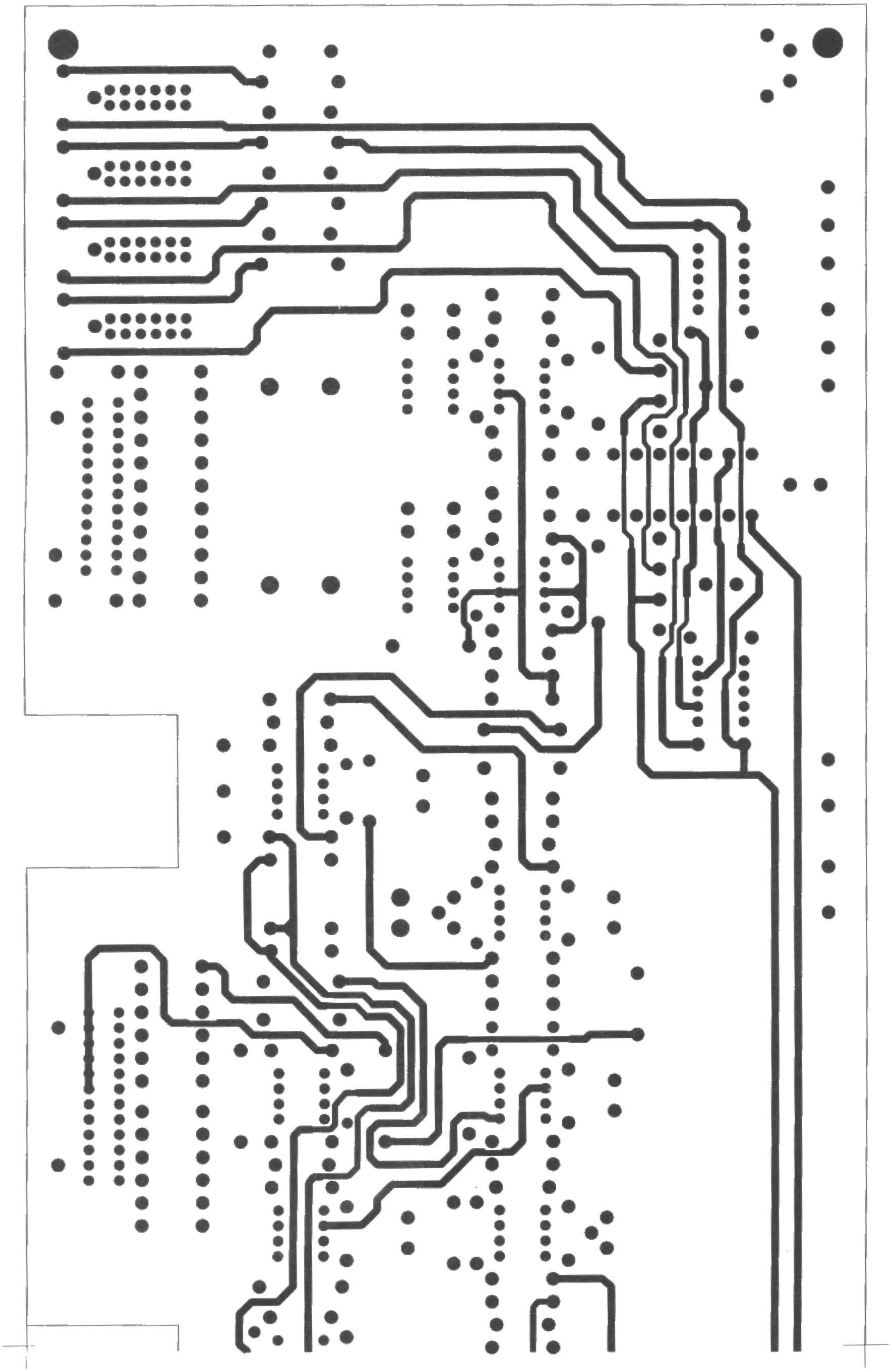

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Around the Corner

Back when I first started as an electronics hobbyist, germanium transistors were all the rage. Well, all there was, actually. When I was at school, I lacked the mathematical training to calculate the base bias requirements accurately (more difficult to optimise because of the very limited gain), and I thought that if I could only learn to understand this abstruse area I really would have electronics sorted out.

Later, op-amp applications, with loop stability calculations, seemed to be the acme of electronics knowledge. After that it was a proper comprehension of the benefits and disadvantages of various approaches to computer architecture.

I think you get the picture.

Nowadays, when considering much of the area of analogue electronics where I specialise, I say "look at where the energy goes". This might sound a bit like a New Age approach - but it isn't. Following the flow of energy in many circuits is the single most important step to understanding how they works and how they may be made to work better. First investigate the real situation - then you can start to apply the maths meaningfully. The electronics engineer needs not a cosmic chant but diagrams, graphs, and numbers.

Another important principle is to think through what happens if a given set of conditions is taken to extremes. For example, if you have a battery with a particular internal resistance, it is well known that the get maximum power from it you must attach a load resistance equal to its internal resistance. If you did not know that answer, you could start to home in on it by reasoning thus:

"If I attach a short circuit, much current will flow but no power will be dissipated in the load. On the other hand, if I attach an arbitrarily high resistance, very little current will flow, so that little power will be dissipated in the load. Once the load resistance is high enough that it causes the battery voltage to sag by only a negligible amount, raising it certainly lowers the power dissipation. Therefore there must be a point in between the two extremes where the power is at a maximum."

This is a simple example, but it can help you to zero in on the general area of the answer in more complicated situations, which may at first appear confusing. Of course, this approach tells you nothing about non-linear regions near to the middle of the problem, but at the minimum it can tell you whether you need to take precautions to avoid one of the outer edges.

The same reasoning can throw light on other fields. As a thought experiment, consider the ideal level of enforcement in a parking scheme intended to be self financing through fines (a topical subject, these days, it seems). Too few wardens and you miss out on fines - too many and nobody overstays their welcome long enough to be fined, plus you pay out more in wages. If you knew how people would react, you could write an equation for it . . .

The above situation includes human beings, who can behave in genuinely puzzling ways. With a recalcitrant circuit, however, as somebody once said, the circuit always works the way it should - it never breaks any law of physics. If you can pin down the place where it appears to do so, you may be able to make it work, or you may at the very least learn something worthwhile and interesting.

For example, last year the design of a card reader, intended to magnetically scan the pattern of aluminium dots on an access control card, started to give problems. The card slid through the reader, magnetic coils energised with a high frequency detected the eddy currents in the aluminium, and the pattern was read. But when the pre-production prototype was built, it read one card and then refused to do anything more for a minute. Eventually I found that the card passing over the plastic generated enough static electricity to raise a big enough electrostatic field to bias off the mosfets in the clock oscillator chip (a surface mount 74HC00). A layer of ground plane under the pcb solved the problem - but who would have thought that a static charge caused by moving a plastic card could prevent a logic chip working almost half an inch away? You cannot predict when electronics will surprise you with an effect that is not obvious until after you have discovered the cause - only that, from time to time, it will indeed surprise you.

The Challenge - *Things that electronics hasn't fixed yet*

Telephone answering machines (with or without computer backup) can call up their owners at a preset time to pass on messages, switch between fax line and voice line in response to a signal, inform callers which services are available and how to access them, and store messages and redirect them at a later date.

How can we train our answering machine to distinguish between a business caller who wants to leave a message and a kindly relative with technophobia - before it connects the call? (Kindly relatives with technophobia hate paying 10p for the privilege of slamming the 'phone down on an answering machine.)

Send your suggestions to the Editor at the address on the right.

Next Month

The January 1996 issue of Electronics Today International is our festive issue of the year. True to the season, there will be flashing lights both micro-controlled and analogue, and even in an unexpected style. Even Rudolph's nose will be flashing (who's going to write a new song about it?). But seriously ... Richard Grodzik presents a PIC16C54-controlled, portable Remote Data Logger that can upload to a PC. There is Part 3 of Barry Porter's MicroAmp. Robert Penfold has built a cable tester that locates the break. Douglas Clarkeson will be in near-space with the International Space Station. And more.

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ABC CONSUMER PRESS ISSN0142-7229

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Subscription rates-UK £25.80 Europe £34.70 Sterling Overseas £36.20 US Dollars Overseas $54.00

Published by Nexus Special Interests, Nexus House, Boundary Way, Hem Hempstead HP2 7ST. Telephone (01442) 66551. UK newstrade distributio by Comag Magazine Marketing, Tavistock Road, West Drayton, Middlese UB77QE. Overseas and non-newstrade sales by Magazine Sal Department, Nexus House, Boundary Way, Hemel Hempstead, HP2 7ST Telephone (01442) 66551. Facsimile (01442) 66998. Subscriptions by Nex Subscription Dept, Tower House, Soverign Park, Lathkill Street, Mark Harborough, Leicestershire, LE 16 9EF .
US subscriptions by Wise Owl Worldwide Publications, 4314 West 23 Street, Torrance, CA90505 USA. For Visa/Mastercard orders in USA Telephone (310) 375 6258 Fax (310) 375 0548. Pacific Time: 9am-9p Weekdays. 10am-6pm Weekends. Typesetting and origination by Ebo Liskeard, Cornwall. Printed by Wiltshire Ltd. Bristol.

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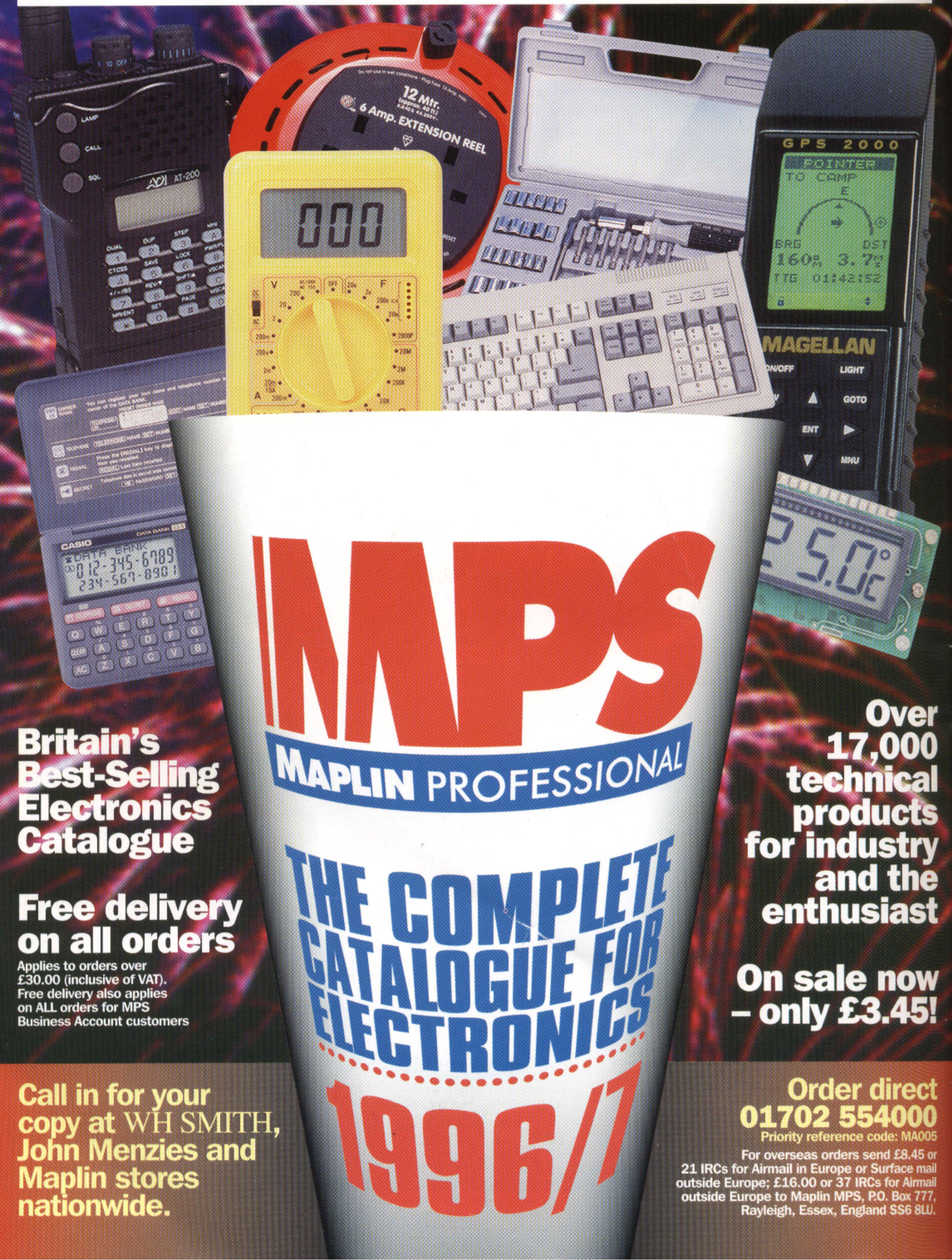

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